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ABSTRACT

The case study of a 78-year-old music composer who had had a stroke revealed that he had a severe reading disturbance, a well-preserved writing ability, and no appreciable aphasia. He continued to read music and to compose. His text and music reading performance under different conditions suggested that this unusual dissociation (alexia without agraphia) was due to four factors: (1) he was unusually talented and knowledgable musically and inferred a great deal about the music he was reading: (2) the symbols of staff music notation are more visually distinctive than the symbols of phonetic language writing systems: (3) in staff music notation, pitch is represented ordinally, and other symbols are also distinguishable by their relative positions and sizes: and (4) in contrast to written language, music notation can be usefully read by interpreting it acoustically, kinesthetically, or in terms of formal musical concepts and it need not be interpreted referentially or in terms of auditory-verbal images. (Author/RL)

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Technical Report #15

ALEXIA WITHOUT AGRAPHIA IN A COMPOSER

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PREFACE

This work constitutes the second chapter of the first author's Ph.D. dissertation (Theodore Lewis Judd, 1979, Towards a Neuromusicology: The Effects of Brain Damage on Music Reading and Musical Creativity, Unpublished Ph.D. Dissertation, Cornell University, Department of Psychology, August, 1979). Portions of this work were presented at the 8th annual meeting of the International Neuropsychological Society, San Francisco, February, 1980.

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ALEXIA WITHOUT AGRAPHIA IN A COMPOSER

I. INTRODUCTION

A. THE ALEXIAS

The study of acquired disorders of reading ability (the alexias) is important in its own right, but also because it has provided a model for developmental disorders in the ability to acquire reading skills (dyslexias) (Hinshelwood, 1917; Denckla & Bowen, 1973). Two major forms of alexia have been widely recognized and a third has been proposed. The first major form, alexia with agraphia, is characterized by a marked disability in reading and writing at all levels including reading aloud and silently, matching words to pictures, identifying letters, and writing spontaneously and to dictation. Copying and writing a few overlearned items such as the patient's signature and address are often preserved. Occasional concrete nouns may be recognized, and semantic reading errors may be presesent, eg. reading "tiger" as "lion" (Gardner & Zurif, 1975). Oral spelling and the comprehension of words spelled orally are typically impaired. These patients are usually unable to recognize letters by tracing them or by having them traced on their hands. Frequently accompanying symptoms are a right hemisensory deficit, autotopagnosia (disorientation to body parts) especially finger agnosia, right-left disorientation, acalculia (impaired arithmetical abilities), fluent aphasia, and, less commonly, right hemiplegia and/or right homonymous hemianopsia (blindness in the right visual field) (Benson & Geschwind, 1969).

The second major syndrome is alexia without agraphia. This is characterized by a marked impairment in reading ability with a relatively well preserved writing ability. Letter recognition and naming, although slow, are typically fairly well preserved, but words are only poorly and slowly recognized, usually by spelling and sounding them out aloud. Letter recognition is often facilitated by tracing the letter with the finger (Charcot, 1877) or even with head or eye movements (Goldstein & Gelb, 1928). Comprehension of letters traced on the hand is usually intact. Although writing is well preserved, these patients typically cannot recognize what they have written a few moments after they complete it. Oral spelling and comprehension of words spelled aloud are typically well preserved. Number reading may be intact as well as recognition of various symbols and of objects presented visually (Gardner & Zurif, 1975). A right homonymous hemianopsia is typically present and there is often a color anomia (inability to name colors) (Geschwind & Fusillo, 1966).

The third proposed alexic syndrome is anterior alexia (Benson, 1977). It accompanies Broca's or motor aphasia and is characterized by an incomplete disability in reading and writing. Typically, letter naming, identification, and writing to dictation are poor, while word recognition, word-picture matching and word writing are better. Concrete words, especially nouns, are handled better than abstract and grammatical words (Gardner & Zurif, 1975). Oral spelling and comprehension of orally spelled words is usually poor. Right hemiplegia is a frequently accompanying symptom, while right hemisensory deficits and right hemianopsias are less commonly seen. The symptoms of the three alexic syndromes are summarized in Table 1.

These syndromes are, of course, abstractions based on the striking dissociations of symptomatology seen in a small minority of patients. They are syndromes only in a weak sense of the term. They do not present an accurate description and categorization of most patients with alexic symptomatology. Few if any really "pure" cases fitting these descriptions have been reported in the literature. Most of the patients seen in the clinic who show reading difficulties fall between these categories or show prominent aphasic or other symptoms as well. Nevertheless, these categories have dominated the literature, and they have proven useful for research purposes and for understanding in the clinic.

B. THEORIES OF ALEXIA

Theoretical explanations of these syndromes have focused primarily on the neuroanatomy of the lesions producing them with relatively less effort being expended in deriving adequate and parsimonious behavioral descriptions of the conditions. The most widely accepted explanation for the two major alexias is that offered by Dejerine (1892). He noted that alexia with agraphia was associated with a lesion of the left angular gyrus, an area of association cortex near the temporal-parietal-occipital junction where visual, auditory, and somesthetic projections converge. He called this gyrus the visual word center and proposed that it is here that the association between the visual or printed forms of words and their auditory representations takes place.

Dejerine also found that alexia without agraphia was associated with lesions of the left occipital lobe and of the splenium of the corpus callosum. The left occipital lobe lesion results in a right homonymous hemianopsia while the splenium lesion destroys the relatively direct connections from the intact visual cortex of the right hemisphere to the angular gyrus on the left. Thus, Dejerine proposed that the visual word center still functions to produce adequate writing, comprehension of oral spelling,

TABLE 1. ALEXIC SYNDROMES

(adapted from Benson, 1977)

Symptom		Alexic Syndrome		
		Posterior	Central	Anterior
Reading	Letters	-	*	*
	Words	*	*	-
Writing		-	*	*
Oral Spelling Comprehension		-	*	*
Spelling Aloud		-	*	*
Aphasia	Fluent	-	±	-
	Non-Fluent	-	-	*
Right Homon. Hemianopsia		*	±	±
Right Hemiplegia		-	*	*
Right Hemianesthesia		-	*	±
Gerstmann Signs[1]		-	*	-

* usually impaired - usually unimpaired ± sometimes impaired

[1] inability to differentiate the fingers, inability to distinguish right from left, inability to perform calculations

and kinesthetic and somesthetic comprehension of letters, but visual information cannot reach it in a form adequate to allow for verbal interpretation.

The disconnection explanation is widely accepted. It has received further support from observations of alexia without agraphia and without hemianopsia resulting from lesions which undercut the angular gyrus posteriorly, thus isolating it from direct visual input (Greenblatt, 1973, 1976; Vincent, Sadowsky, Saunders, & Reeves, 1977; Luekdorf & Paulson, 1977; Johansson & Fahlgren, 1979). Still more support comes from observations of alexia without agraphia with left homonymous hemianopsia resulting from lesions of the right occipital lobe and the splenium of the corpus callosum in persons showing evidence of right hemisphere lateralization of language functions (Fincham, Nibbelauk, & Aschenbrener, 1975; Hirose, Kin, & Murakami, 1977; Hirose, 1978).

Some authors have explained cases of alexia without agraphia by competing hypotheses such as severe visual-perceptual disorders (Gloning, Gloning, & Hoff, 1968; Adler, 1944; Wolpert, 1924), or eye movement disorders (Warrington & Zangwill, 1957). But the possibility of extending these explanations to all cases of alexia without agraphia has been ruled out by careful examination of select cases showing the absence of such signs and by the demonstration of cases which show severe visual-perceptual or eye movement disorders without alexia (Benson & Geschwind, 1969).

Benson (1977) has suggested that his proposed anterior alexia can be explained as the combined effects of a number of symptoms associated with left frontal lobe lesions and expressive aphasia. These include disordered eye movements, especially a difficulty in moving the eyes to the right, difficulty in maintaining a sequence of verbal information, difficulty in interpreting grammatical structures, and difficulty in naming letters. Thus, he suggests that reading involves a complex set of activities involving many parts of the brain and that it can be disturbed in characteristic ways by lesions in different anatomical locations.

Charcot (1877) suggested that anterior alexia occurs in people who are semi-literate and must read aloud and for whom this has become impossible due to dysarthria (impairment in articulation). This explanation has not been systematically explored, but it seems unlikely in view of Benson's (1977) study. He found that 51 of his population of 61 U.S. veterans with anterior aphasia showed signs of alexia. It is improbable that such a high proportion of this population would have been so poorly literate premorbidly.

A weaker version of this hypothesis might be compatible with these data, however. Articulatory pathways are

typically involved in learning to read (at least with a phonetic system) as Charcot pointed out. These pathways might still be involved when vocalization becomes suppressed to subvocalization and even when no articulatory movements are detectable, at least for a large class of readers and a large set of reading circumstances. Gibson and Levin (1975) observe that even in the mature reader, subvocalization is an important part of the reading strategy repertoire. Retreating further into cognition, analysis by synthesis (Goodman, 1967) and other active strategy (Gibson & Levin, 1975) accounts of mature reading are also suggestive of a possible role for the left frontal lobe and other brain areas in many aspects of reading.

While the visual word center and disconnection explanations have been widely accepted as accounting for prominent features of the central (alexia with agraphia) and posterior (alexia without agraphia) syndromes, they leave many aspects unexplained. For instance, why is the left angular gyrus singled out for reading from among the other areas which receive converging multi-modal sensory inputs such as the right angular gyrus or other areas of the frontal and parietal lobes? It appears that an adequate explanation of why the left angular gyrus appears in some respects to function as a visual word center must await an adequate explanation of the development of localization of function in the brain.

Another source of difficulty with the visual word center-disconnection explanations of the major alexias is that the variably accompanying symptoms are not adequately explained. If alexia without agraphia is the result of a visual-verbal disconnection, why do such patients not always show a visual anomia (inability to name objects presented visually)? Why is color anomia variably associated with the syndrome? Why are number and letter reading sometimes preserved? Benson and Geschwind (1969) suggested that reading and color naming are pure visual-verbal associations, whereas object naming and number reading may take place via other association pathways. This account has some plausibility as an initial attempt at an explanation, but it would be more satisfying if there was not so much unaccounted-for case-to-case variability in the presence of these symptoms.

In recent years much research has attempted to determine the nature of cerebral specialization of function in terms that focus on the stimulus properties and behavioral requirements of the test activity. Thus, instead of talking about various word centers in the left hemisphere, investigators are attempting to determine the stimulus and task demand properties which typically engage the activity

of different parts of the brain. For instance, theorists have suggested that the left hemisphere is not only verbal, but that it is also specialized for fine motor skills (Wolff, 1977), for handling material in which temporal sequencing is important (Albert, 1972), and/or for handling familiar, identifiable material (Wada, 1977). In fact, many theorists feel that these more broadly defined specializations may account for the left hemisphere's verbal specialization.

C. READING DISORDERS IN JAPANESE

The alexias can be expected to provide evidence relevant to these theories and at the same time these theories may suggest a more accurate and parsimonious description of alexic syndromes. One way in which this can happen is by examining brain-damaged patients who possess reading skills different from those which dominate the literature. The Japanese language has two writing systems which are ideally suited for such study. The Kana system is phonetic—it is a syllabary, i.e. there is a 46 character "alphabet" consisting of one character for each syllable (actually one character for each mora). The Kanji system is ideographic: crudely speaking there is a different character for each word or idea, amounting to thousands of characters. All Kanji words can be expressed in Kana, but the reverse is not true. For most purposes both systems are used together in a hybrid phonetic-ideographic system; thus a root word might be written in Kanji and its grammatical ending in Kana.

Most Japanese aphasics, including most expressive and receptive aphasics, are more impaired in Kana use than in Kanji use (Sasanuma, 1975). They tend to make phonemic substitution errors in Kana. A few aphasics described as showing mixed transcortical aphasia, semantic aphasia, or isolation of the speech areas show greater impairment in Kanji than in Kana (Sasanuma & Monoi, 1975). These are patients with lesions around the speech areas but with little pathological involvement of those areas. They tend to show fluent speech, good auditory reception, good repetition, good reading aloud, and good writing to dictation, but poor language comprehension and use. Their language skills do not connect usefully and reliably to their non-verbal behavior. They tend to make homonym substitution errors in Kanji, that is, they use the characters as phonetic symbols disregarding their meanings.

The dissociation between these two types of reading disorders suggests two distinct reading modes and neuroanatomical substrata, one being primarily phonetic and the other primarily semantic. This is suggestive of the distinction between pure visual-verbal associations and other association pathways which Benson and Geschwind (1969)

suggested might help explain some of the symptomatology of alexia without agraphia. For instance, Western writing systems are hybrid phonetic-ideographic systems as is Japanese, although the ideographic compontents are minor, eg. #, %, $, @, &, ?, !, +, =, 1, 2, 3, etc. The relative preservation of number and symbol reading in some Western alexic patients may reflect a relative sparing of the ideographic or semantic reading system as has been dramatically demonstrated in Japanese aphasics. This speculation awaits confirmation in non-aphasic alexic Japanese patients. The neurological distinction between semantic or ideographic and phonologic reading systems is further supported by the relative sparing in some Western aphasics and central alexics of the ability to read concrete nouns, and by their tendency to make semantic reading errors (Gardner & Zurif, 1975). Still other Western aphasics have shown relatively selective impairments in phonological reading in that they are unable to read nonsense words (eg. "dake") or phonological equivalents of real words (eg. "flore") (Patterson & Marcel, 1977; Saffran & Marin, 1977).

D. DISORDERS OF MUSIC READING

1. Music Notation

The fate of music reading in alexia in appropriate cases could also prove useful in testing and elaborating theories of alexia, of reading, and of neuroanatomical specialization. For the musically literate, music reading involves a familiar visual symbol system, fine motor activity, sequential material, visual-auditory associations, visual-verbal associations, and visual-motor associations. Many of these aspects of the system can be more-or-less selectively evoked by varying the music reading task.

Before reviewing this literature it is necessary to describe briefly the nature of music notation systems and their common uses. Music and language notation systems share the feature of a linear representation of the time dimension on the page. Most of the language and music notation systems in widespread use today also share to some extent the feature of being phonetic, that is, in a loose sense each arbitrary symbol stands for a component sound or the actions necessary to produce that sound in the communication system being symbolized. In addition, most music notation systems in widespread use currently, including the staff notation system in question here, share the feature of a linear representation of another dimension, namely the pitch of the musical notes. Thus while the phonetics of language writing systems is nominal with different arbitrary symbols standing as the written "names" of different speech sounds, the "phonetics" of staff music notation is in part ordinal— notes higher in pitch are always represented higher on the

page, although there is no direct correspondence between the distance between notes on the staff and their separation in pitch. (Actually, this is called a "diastematic" representation of pitch, not a "phonetic" representation.)

As with most language writing systems, music notations are usually hybrids of phonetic and ideographic systems. In staff music notation there are many ideographs and these play a more important role than do the ideographs in written English. They include the clef signs, tempo and dynamic indications, repeat signs, and indications of expression, to name but a few. While they can be represented by words, they represent "ideas" about the music or even about the process of reading the music at a wide variety of levels. For instance, bar lines have little if any easily definable representation in sound; they represent instead a way of thinking about the span of time in which the music takes place. Repeat signs, first and second endings, etc. indicate how the piece is to be read for performance. Clef signs, staff and ledger lines, and tempo indications all establish a frame of reference for the phonetic symbols.

Gibson and Levin (1975) have reviewed the graphic features of language writing systems. Most of those features also describe most music notation systems, but two major differences need to be noted. Most language writing systems have gaps that mark graphic and linguistic units. But in staff music notation most of the phonetic symbols are tied together visually by the lines of the staff and the note stems. Bar lines serve some of the same functions in staff notation as do spaces in written language, but visually they are very different. Also, most language writing systems have symbols of roughly similar size, but the symbols of staff music notation vary greatly in their size.

2. Music Reading

There are many different ways of reading music in common practice (Sloboda, 1978), just as there are many different ways of reading text (Gibson & Levin, 1975). It is possible to "read" music by naming or describing all of the symbols on the page. A proofreader might be concerned only that musically equivalent configurations are preserved. More commonly, an instrumentalist might read music by translating the visual symbols into motor activity with respect to an instrument and thus produce the appropriate sounds. A singer would be more likely to translate the visual symbols of music notation into imaginary sounds and then sing those sounds. A conductor might read a score by translating the symbols into auditory imagery in order to arrive at an emotional interpretation. A scholar or composer may sometimes translate the visual symbols of music notation into a theoretical (possibly

verbal) representation without passing through either auditory or motor imagery. A copyist or transcriber might pass from one form of music notation to another with no auditory, motor or theoretical imagery. Some music readers are skilled in only a few of these modes of reading, while others are able to use any of these strategies (Bean, 1938; Sloboda, 1976). Unfortunately, these different ways of reading music have become very confused in the neurological literature.

Research in the psychology of music reading has been largely confined to mature readers sight-reading staff notation while playing the piano (Sloboda, 1978). These subjects typically read several (3-11) notes ahead of what they are playing, just as mature text readers read several words ahead of what they are saying when reading aloud. They use the structure of the music and the structure of the notation to help them read patterns of notes and they infer quite a bit about the music on the basis of their knowledge of musical structure. In fact, they often fail to notice proofreaders errors and play instead the correct notes inferred from the context.

3. Case Histories

The effects of brain damage on music reading abilities have been reviewed by Henschen (1920) and by Feuchtwanger (1930). In addition, reviews of the amusias (Edgren, 1895; Ingegnieros, 1906; Dupré & Nathan, 1911; Ustvedt, 1937; Wertheim, 1969; Gates & Bradshaw, 1977; Benton, 1977) and the alexias (Bastian, 1898; Holmes, 1950; Benson & Geschwind, 1969; Levin & Rose, 1979) make passing references to the problem and Henson (1977) has discussed it without reviewing the literature. I will present here summaries of the cases most often referred to in the literature concerning music reading and writing abilities. Second hand references are included and identified as such when I have been unable to locate the original case report in order to make the review more thorough and representative. First I will review the cases in which music reading and/or writing skills were said to be in some sense better than the analogous language skills, then the cases showing similar impairments in both, and finally the cases reported to show an impairment in musical lexical skills greater than that in language lexical skills, each in chronological order. The cases are summarized in Table 2.

a. Music Reading "Better" Than Language Reading

Bouillaud, 1865. A 50 year old man awoke to find that he was unable to express his thoughts in words. Although he thought clearly, when he tried to speak his words became mixed up. Two months later he was painfully slowly able to make himself understood in good moments. At three months he was able to write letters and his name but no other words

TABLE 2. MUSIC READING CASES

** severely impaired * mildly impaired - unimpaired ◯ questionable L left R right
F frontal lobe T temporal lobe P parietal lobe O occipital lobe S splenium

Author	Background	Etiology	Lesion	Course	Hemiplegia	Hemianesthesia	Hemianopsia	Aphasia	Amusia	Color Naming	Comp. Oral Spell.	Reading: Language: Letters	Reading: Language: Words	Reading: Language: Numbers	Reading: Music: Naming	Reading: Music: Performing	Writing: Language	Writing: Music
MUSIC READING "BETTER" THAN LANGUAGE READING																		
Bouillaud, 1865	composer			stable				**	◯				*	*		-	**	-
Proust, 1872 A	good musician							**	*								**	◯
Proust, 1872 B	intelligent, musical				**			**	*			*	*	*	◯	◯	**	-
Bernhardt, 1872				stable	**		**	*	◯			**	**	**	◯	◯	◯	
Anton, 1888	violinist, alcoholic			improving				*	-	**		*	*			◯	◯	
Oppenheim, 1888	violinist			slow onset stable		**	**	**	*							*	**	**
Hinshelwood, 1902	educated	syphilis		recurrent transient				*				◯	**	-	◯	◯		
Hinshelwood, 1917	15 yr. old pianist												**			-		
Souques & Baruk, 1926	professor of piano	stroke	L T & ang. gyr.	uncertain	-	-	-	**	**			**	**	◯		*	**	◯
Ingham & Nielsen, 1936	amateur musician	glioma, surgery	L T	stable, fatigues	-	-	-	**	◯			*		◯		◯		

TABLE 2. (Continued)

** severely impaired * mildly impaired - unimpaired (○) questionable L left R right
F frontal lobe T temporal lobe P parietal lobe O occipital lobe S splenium

Author	Background	Etiology	Lesion	Course	Hemiplegia	Hemianesthesia	Hemianopsia	Aphasia	Amusia	Color Naming	Comp. Oral Spell.	Reading: Language: Letters	Reading: Language: Words	Reading: Language: Numbers	Reading: Music: Naming	Reading: Music: Performing	Writing: Language	Writing: Music
Casey & Ettlinger, 1960	theatrical entertainer	hemorrhage	L O	transient	-	-	**	-		*		**	**	**	(*)	(-)	**	(-)
Luria, et.al., 1965	composer professor	strokes	L TP	stable at testing	*	*	-	**	(-)			-	*	-		(-)	*	-
Assal, 1973	light music pianist, bass	stroke	L T	stable at testing	-	-	-	**	-			*	*	(-)	*	-	*	-
Assal & Hadj-Djilani, 1976	farmer	tumor	L TP	gradual onset	-	-	-	(*)				-	*	-	-		*	
MUSIC AND LANGUAGE READING EQUALLY IMPAIRED																		
Fischer, 1863	composer teacher				**			**							(**)	**		*
Frankl-Hochwart, 1891	merchant, violinist	(syphilis)		recurrent	**			**	(*)				(*)			**	**	**
Dejerine, 1891	businessman singer	stroke	L O S	stable at testing	-	-	**	-	-			**	**	-	**	**	-	(*)
Poetzl, 1927	businessman	(stroke)		stable at testing	(*)	**	**	(*)	(-)	**		**	**	(*)	(*)		(-)	
Holmes, 1950	physician			stable at testing	-	-	**	-		**	-	**	**	-	(**)		-	
Jellinek, 1956	popular singer guitar, piano	tumor surgery	L F	stable at testing	**	-	-	**	**			(**)	(**)	(**)	(**)	(**)	**	

TABLE 2. (Continued)

** severely impaired * mildly impaired - unimpaired ◯ questionable L left R right
F frontal lobe T temporal lobe P parietal lobe O occipital lobe S splenium

Author	Background	Etiology	Lesion	Course	Hemiplegia	Hemianesthesia	Hemianopsia	Aphasia	Amusia	Color Naming	Comp. Oral Spell.	Reading: Language: Letters	Reading: Language: Words	Reading: Language: Numbers	Reading: Music: Naming	Reading: Music: Performing	Writing: Language	Writing: Music
Dorgeuille, 1966 A	carpenter violin	angioma surgery	L TPO	stable at testing	-	-	**	**	◯	✱		**	**	**		**	✱	
Levin & Rose, 1979	drummer	meningioma surgery	L O S	stable at testing	-	-	**	✱	◯	**		**	**	**	**	**	-	
LANGUAGE READING "BETTER" THAN MUSIC READING																		
Proust, 1866									-						✱✱	✱✱		-
Finkelnburg, 1870	teacher, violin student	hemorrhage	R insula, striat.	transient	* L			*								*	*	*
Charcot, 1883 A	professor distinq. musician	syphilis		progressive	-	-	-	-	-							**		
Charcot, 1883 B	trombonist, music copyist	syphilis		progressive	-	-	-	-	*								◯	✱✱
Brazier, 1892	piano teacher	migraine		transient	-	-	-	-	✱			-	-	-		**		
Wuertzen, 1903	violinist	stroke		stable at testing	*	**	-	-	**						◯	✱✱		
Jossmann, 1926	teacher, violin singer	stroke		stable at testing	*			-	**						✱	**		-
Dorgeuille, 1966 B	chorister sight-sings	thrombotic stroke		stable at testing	* L	* L	-	*	*			-	-	-		**	✱	✱

correctly. He was able to read and understand complete sentences, but not aloud. He performed an addition problem only with great difficulty. When his wife asked him to compose something he wrote a piece which was completely correct. He then read the melody correctly, humming it and playing the notes on the piano.

Proust, 1872 (A). A patient was able to write with facility the music of melodies he had heard, although in other respects he suffered from complete aphasia and agraphia.

Proust, 1872 (B). An intelligent, artistic, musical woman had a sudden onset of right hemiplegia and loss of speech. She recognized objects and she understood everything that was said to her, but she was unable to say even her name. When she tried to read aloud she produced only a mixture of unarticulated sounds without any sense. She read rapidly and understood everything she read. Her spontaneous writing was unintelligible, but she was able to copy accurately. She knew her notes, made scales, and recognized melodies, but she was unable to hum.

Bernhardt, 1872. A 52 year old man was seen 15 months after the onset of right hemiplegia and a language disturbance. On examination he showed a right homonymous hemianopsia. He showed flowing speech and even a press of speech (excessive output), and there was an anomia with some circumlocution. He was able to write correct letters and words with his left hand, but he was unable to read them. He read numbers as poorly as letters. He recognized musical notes and named them a little better than he named letters. He was able to read notes correctly in order to sing a melody, but he was unable to read the words of the song along with it. He was able, however, to sing well-known songs with the words from memory.

Comment--This is probably a case of alexia secondary to aphasia rather than a posterior alexia. The reading task was apparently to read aloud from his own handwriting.

Anton, 1888. A 48 year old violinist with a 10 year history of alcoholism had an attack of vertigo and lost consciousness. He awoke confused and was admitted to a psychiatric hospital. He gave completely senseless answers to questions on admission and seemed unaware of his misperceptions. Two days later he was able to make some of his wishes known but still could not answer questions. At two weeks he could answer some questions but not unexpected ones.

At three weeks he gave an account of his illness and answered questions about it but still not unexpected questions. His speech repetition was excellent. He made errors in naming objects. He made some errors of mixing up

his words. When given something to read he read very slowly aloud, sounding out the words but without comprehension. He said that he thought they had given him Latin to read. He wrote letters and words to dictation flawlessly, and was able to write several words of a sentence to dictation on one presentation. He made errors in trying to name colors, but he sorted colors well and showed no signs of color-blindness. If someone started singing a song he was able to sing the melody quite well without the words, but he could not do this if given only the title. He read music correctly and rapidly, either singing or on the violin. When singing he sang with solfeggio syllables. He played pieces from memory very well and improvised variations.

Comment--This case, which Anton called "pure word deafness," sounds more like isolation of the speech areas. Reading is done phonetically, but without comprehension.

Oppenheim, 1888 (cited by Edgren, 1895; Henschen, 1920). A 35 year old musician with a 2 1/2 year history of seizures with loss of consciousness was examined 3 months after the onset of a speech disturbance. He had a right homonymous hemianopsia and hemianesthesia. He showed no spontaneous speech. He was able to get a few words out in answer to questions, then came to a stand-still. He failed to understand a few spoken sentences that contained unusual words. He was unable to write even his name or to dictation, but he was able to copy somewhat. He was able to copy geometric forms.

He was unable to sing a melody given its name, but if the first few notes were sung he was able to complete it. His singing repetition was good. He enjoyed playing musical excerpts on the violin, but he soon lost the thread. He recognized pieces of music from a score placed before him. He was able to sight-read music on the violin, but when the piece was unfamiliar he went very slowly and made many mistakes. He no longer sounded beautiful; he sounded like a beginner. He was able to write a C major scale, a C major chord and similar material without very much reflection.

Hinshelwood, 1902. A 34 year old highly-educated French teacher was examined one week after the sudden onset of a complete aphasia which showed a rapid clearing. He had had an attack of left hemiplegia three years earlier from which he had fully recovered. On examination he showed word-finding difficulty and occasional word substitutions and minor difficulties in auditory comprehension. When tested in English he was able to read all letters with only occasional errors and he could read a few of the smaller words, but he was unable to read longer words except by spelling them aloud. Surprisingly, he was able to read Greek fluently and Latin almost as well, while his native French was only a little better than English. He read

numbers easily and performed addition and subtraction correctly, but not multiplication or division. He wrote to dictation with some difficulty and made a good many mistakes. "He read musical notes as fluently and correctly as ever he did, without manifesting the slightest hesitation."

Six weeks later he was able to read correctly, but was still slow in English. Three months after the attack he was almost completely recovered in all areas. He later developed a right hemiplegia and aphasia and died within a year of the attack described above, presumably of neurosyphilis.

Hinshelwood, 1917. "A girl of 15 years of age, had become completely word-blind from cerebral disease. She could not read a single word of a song, but could read the music. Being a good musician and not being able to read books, she spent a large part of her time at the piano, playing page after page of music."

Souques & Baruk, 1926. A 70 year old professor of piano was admitted to the hospital with a fluent aphasia of uncertain onset. Her neurologic exam was normal. Her spontaneous speech was fluent, rapid, and unintelligible. She was poor at executing spoken commands. She performed no commands presented in written form and apparently understood no written words and only a few letters. Her writing was equally disturbed. She was somtimes able to write her own name and nothing else. She was able to count to 10, to copy numbers, to write numbers to dictation and to do simple addition.

At the piano she played one particular dance over and over again with agility and good rhythm, but a little jerky and with a few wrong notes. She was able to play some exercises such as scales correctly. She seemed not to recognize well-known tunes or errors in performance if she was unable to see the hands on the keyboard. She was able to sight read easy sonatas at the piano quite well, but had a great deal of difficulty with a prelude from Bach's Well Tempered Clavier. She named the notes easily with only a few rare errors. She was able to sight-sing well including accidentals and with no rhythmic errors. She was able to copy music well, but she was not able to transpose from treble clef to bass clef. She was able to recognize some notes by ear to take dictation.

Autopsy (Souques & Baruk, 1930) showed a degeneration and softening of almost the entire left temporal lobe and the white matter underlying the angular gyrus, while the rest of the brain was normal.

Ingham & Nielsen, 1936. A 41 year old amateur musician had a complete left temporal lobectomy for a malignant glioma. Following surgery he was able to speak fluently and

entirely correctly for a fraction of a minute at a time and then broke down into neologisms and jargon until rest intervened. His auditory comprehension was similarly good for a fraction of a minute at a time. He was able to recognize written language, but he was unable to comprehend its meaning. For instance, he was able to sort typewritten sentences that had only slight differences in them, but he failed to place written names on their appropriate objects. He was also unable to write and unable to spell out words when he was given anagrams. Calculation, music appreciation, music performance, and music reading were all unaffected.

Casey & Ettlinger, 1960. A 45 year old right-handed theatrical entertainer was examined 5 days after the sudden onset of severe, throbbing, bifrontal headache, vomiting, difficulty seeing to the right, diplopia, and inability to read. On examination he showed a right homonymous hemianopsia with some slight sparing of the lower quadrant and no diplopia. There was a suggestion of astereognosis in the right hand and a subtle confusion in pointing to body parts. He had normal speech, but a tendency to perseverate in object naming. He was unable to read or spell words aloud. Writing to dictation was grossly abnormal, while spontaneous writing was not as severely impaired. Left carotid arteriography led to the presumptive diagnosis of hemorrhage from a left occipital arteriovenous malformation, confirmed in part by spinal tap, E.E.G. and otological examination.

Although he was initially unable to identify any letters, he improved rapidly, so that within three weeks of his injury he was making only occasional mistakes. Word reading had been similarly impaired but within 4 weeks of his injury he read 92/100 short words correctly, and his errors appeared to be visual confusions. He was better at reading words in connected prose, getting 80% correct only 2 weeks after his injury. The recovery of reading comprehension paralleled the recovery of the ability to decipher text aloud. Number and clock reading recovered in a pattern similar to that for letters. His color naming was initially moderately impaired but recovered with his reading. His ability to write letters and words to dictation recovered gradually over a four week period along with his reading.

"In contrast to his defective recognition of letters, words, symbols, and numerals was his ability to read musical notation apparently as well as he had ever done so. He had in fact never studied music but learnt a rhyme which enabled him to read certain notes. These, with one mistake, he identified with apparent ease [at one week]. He read not very distinct flat and sharp notations quite easily, scoring 94% correct overall for music notation. [At 2 and 4 weeks] he was asked to make written records of short rhythms tapped

with a pencil on a table. His records were correct within the framework of his own notation in 80% of attempts on both of these dates. When asked thereupon to reproduce the rhythms by tapping and reading from these written records, he successfully interpreted his own notation in 90% of trials [on week 2] and 100% [on week 4]."

Luria, Tsvetkova & Futer, 1965. Shebalin was a Russian composer and professor of music. At age 51 he suffered a stroke with a right hemiparesis, mild sensory loss in his right hand and a severe speech disturbance. These symptoms cleared in a few weeks. Six years later he had a second stroke with loss of consciousness and right hemiparesis and sensory loss. He also had a severe speech disturbance. The motor and sensory losses gradually cleared leaving only mild residuals. Two years later he had a seizure and he died a year later following a third stroke.

For the first few weeks following his second stroke his speech output was very limited. He recovered his ability to articulate, but he made many paraphasias. These were present in spontaneous speech, object naming, repetition, and series speech (reciting the days of the week, etc.). His auditory comprehension showed considerable "alienation of word meanings," i.e., the words sounded unfamiliar to him. His ability to comprehend fatigued rapidly. "Reading was preserved, and to some extent writing, but he remained unable to write down long words, or a series of words or phrases. When fatigued he would become unable to grasp the meaning of written phrases or paragraphs.

"Throughout the whole three year period, no significant alteration in personality could be observed. In spite of the severe affection of speech the patient continued his work as a composer. He worked hard with his pupils, listening to their compositions, analysing and correcting them. He spent a considerable time over his own creative work." He wrote a number of successful new compositions which were considered up to his standards. Autopsy showed "a massive red softening of the left hemisphere in the temporal and inferior parietal regions, with a hemorrhagic cyst of the left temporo-parietal region."

Assal, 1973. A 64 year old clerical worker and light music pianist and string bass player experienced a sudden onset of a severe Wernicke's aphasia, probably due to an embolus from an ulcerated plaque in the left internal carotid artery. Five weeks later he received a carotid endarterectomy, and he was examined during the following week. He showed fluent speech with word-finding pauses. Repetition was poor with both literal and verbal paraphasias present. Auditory comprehension was poor. Reading comprehension was poor, and in reading aloud he made errors of visual confusion. His writing showed neologisms and

jargon. Simple calculations were preserved, but he made errors on more difficult problems. He had a WAIS Performance I.Q. of 93. He continued to play his instruments, and musical colleagues with whom he performed were completely satisfied with his abilities. Although he sometimes failed to recognize the titles of pieces when they were said to him or presented in writing, he could play them if the beginnings were played for him, or if he saw the music notation for them. He was able to sight-read music at the piano, although he had some difficulties with rhythms. He was completely unable to name musical symbols, however. Writing notes from verbal dictation was difficult, and he had never learned to take musical dictation. But he was able to copy music adequately and to write down short melodies that he composed.

Assal and Hadj-Djilani, 1976. A 58 year old, right-handed farmer noticed a decline in his ability to read. Examination revealed that he made occasional speech errors. Repetition and auditory comprehension were good. He was able to identify letters, numbers, and other verbal symbols well, but he made many errors when trying to read words, and his reading was very slow and effortful. In attempting to read prose passages he showed considerable guessing at the contents from the context. Calculations were good both mental and written. He generally formed letters well when writing but made a number of spelling errors, ommissions, and substitutions.

In reading music he showed a good knowledge of the names of the notes and their temporal values and of the other musical signs. He showed no signs of visual agnosia and his ability to draw and make other constructions was good. He showed no visual-spatial difficulty on tests of visual recognition. He made one error in naming ten colors. He had no visual field defect.

Radiographic investigations revealed a mass at the left temporal-parietal-occipital junction. A hematoma was removed from beneath the angular gyrus. Following surgery his reading remained the same, but his writing and calculations deteriorated. Six weeks later he had recovered completely except for some fatigue in reading and occasional spelling errors.

b. Music and Language Reading Equally Impaired

Fischer, 1863 (cited by Henschen, 1920; Feuchtwanger, 1930; Ustvedt, 1937). A 42 year old composer and music teacher had a right hemiplegia and aphasia. He showed apraxia, alexia, and agraphia. He was unable to match a pitch singing or on the violin. He was able to recognize his own composition. He was unable to read music, and he wrote notes poorly. His rhythmic sense seemed to be intact.

Frankl-Hochwart, 1891. A 24 year old merchant and

violinist with a history of syphilis experienced a headache followed by left hemiplegia which cleared in a week. A week later he experienced a sudden right hemiplegia and complete aphasia. After a month he recovered some movement, but the aphasia persisted. He was only able to produce about 6 words spontaneously, although repetition was better. Auditory comprehension was good. He was able to read and to indicate errors in the examiner's reading aloud. He could write very little either spontaneously or to dictation. He was unable to play, sing or whistle any melody either spontaneously or from the title, but when someone else sang he was able to continue, and he was able to repeat things sung to him. He did not recognize written melodies, nor was he able to sing or whistle them, but he sometimes succeeded in playing them on the violin (with his left hand on the finger board and the examiner plucking the strings). He could not write down any melodies, but he wrote down several notes with their letter names.

Dejerine, 1892. A 65 year old, well-educated businessman and singer experienced brief episodes of reduced sensation and weakness on his right side and impairments in speech. A week later he noticed that he was unable to read. Examination revealed a right homonymous hemianopsia and an inability to read letters or words. He was sometimes able to recognize letters if he traced them with his finger. Writing was intact as was the reading of numbers and calculation abilities, although calculations were slowed. There was no disturbance of speech or of singing music. Although he was unable to sight-read or identify musical notes, he was able to write notes of different time value to dictation.

A year later he had another stroke leaving him aphasic and unable to write or sing. He died 10 days later. Autopsy revealed a fresh lesion in the left inferior parietal lobe and several old lesions involving the left occipital lobe and the splenium of the corpus callosum.

Poetzl, 1927. A 65 year old hypertensive businessman experienced an episode of objects swimming before his eyes and a flushed face. 600 ml. of blood were removed and he went into a stupor. On recovering he was blind which resolved the next week into a right homonymous hemianopsia. He had an impairment of sensation on the right and his right hand was slightly ataxic. He showed an amnestic aphasia (mainly word-finding difficulty), a general memory disorder, and a severe reading disorder. A seizure condition developed with an aura beginning in the right thumb.

Further examination revealed that he was generally unable to read letters, but tracing them with his finger helped him to recognize them. He wrote letters, words and sentences very well to dictation. He read digits correctly,

but was unable to read "12" as "twelve" and read it as "one, two" instead.

He was able to play the piano well. He could differentiate printed music from other printed material, and he could identify the time signature, the clefs and the notes. But when asked to give the letter names of the written notes and their time values he got the first one correct then perseverated and confused the others.

He recognized and described pictures adequately, except that with complex scenes he showed a tendency to describe only small portions of the scene. He was unable to name colors correctly. He showed a subtle impairment in his ability to identify his body parts.

Holmes, 1950. A 72 year old physician noticed that he was unable to read. He also noticed that he was slightly clumsy with his hands, and that he was not as quick at card games as he had been. He was examined a month later and followed for two years during which time his condition remained stable. He had a right hemianopsia with some sparing of the macula and the inferior periphery. Visual acuity was normal. His speech was normal except for occasional word-finding pauses. He was usually unable to identify letters or words. He was, however, able to recognize words spelled orally. Although unable to read words, he was often able to match objects to their written names or to pick out a word when given a description of the object. Tracing letters with a pencil sometimes aided him in identifying them. He complained, "I feel I can read the letters, but when I try they seem to get mixed up and blurred," and when there were two or more letters present he would comment, "I don't know what letter I am trying to see." Identifying by touch large letters cut out of cardboard was variable.

He identified numbers easily and usually could identify three or four digits together. He could solve fairly difficult arithmetic problems with only occasional errors in alignment. He wrote very well both spontaneously and to dictation.

"Formerly he read music, but when he was shown a few bars, he was unable to name the notes and said that as musical symbols they meant nothing to him."

He made occasional errors in reading clocks. He had no difficulty finding his way, in following maps or in drawing maps. He recognized objects and line drawings readily, including drawings in perspective and complex scenes. He was poor in naming colors and in picking out colors from their names except for red. He could tell what color familiar objects that were not in vision were and he could say how he would mix paints to get a certain hue.

Jellinek, 1956. A 46 year old professional guitarist,

piano player and popular singer had a left frontal glioma removed. Following surgery he had a right hemiplegia, expressive aphasia, disorders of reading, and was completely agraphic. He showed ideo-motor apraxia. His arithmetic was poor and his visual Gestalt perception was diminished. He had had little formal schooling in music and played popular music by ear. He repeated tapped rhythms poorly and was unaware of his errors. He sang with a poor voice and poor intonation. He was especially poor in dealing with musical terms and was completely musically alexic.

Dorgeuille, 1966 (A) (Case 5). A 47 year old right-handed carpenter with a background of musical training in singing and violin had a large angioma removed from the left posterior parietal and temporo-occipital region. An examination three years later showed a right hyperreflexia and right hemianopsia. He showed a severe sensory aphasia with many paraphasias and naming errors in his spontaneous speech. Repetition was poor. He made many errors in trying to read letters and words. He made a few errors in writing words to dictation and many substitutions in writing numbers to dictation. Calculations were severely impaired, and he showed some disorientation to body parts. He had difficulty recognizing drawings and colors.

He sang, matched pitches, and copied music correctly. He reproduced rhythms adequately and identified instruments and melodies but not styles. He was unable to sight-sing music.

Levin & Rose, 1979. A 58 year old drummer had a meningioma removed from the left lateral ventrical by a transcallosal approach. During surgery the occipital tip became necrotic and 3.5 cm. of it were removed. Post-surgically he showed aphasia, right hemiplegia and right hemianopsia.

42 days after surgery an examination showed a dense, complete right hemianopsia, occasional hesitation in speech and a severe alexia. He was completely unable to read words, letters, or numbers, but writing was unimpaired. He was poor at identifying objects presented visually and tactually and in pointing to objects from their names, but he was able to name all of the same objects from their verbal descriptions. He was unable to name colors correctly, but he was able to sort them accurately. He was severely impaired in his ability to read musical notes and to point to notes named by the examiner. He was better able to interpret musical symbols such as the clefs, key signatures, and note heads when presented within the context of sheet music.

c. Language Reading "Better" Than Music Reading

Proust, 1866 (cited by Edgren, 1895; Ingegnieros, 1906; Benton, 1977). A patient lost the ability to read music but

could sing, write music, and comprehend music normally.

Finkelnburg, 1870. A 36 year old teacher who had been playing the violin for 12 years had a 3 year history of spasms in the left hand. While playing a difficult exercise he experienced a spasm in his left hand which also extended to his face. After that he was unable to find the proper words for things and he had a slight weakness in his left hand, but he continued with his exercises. He found, however, that he was only able to read and play the notes with great difficulty and frequent confusions. He was able to repeat heard melodies on the violin, but not on the piano. He made many mistakes in taking musical dictation. His writing was as impaired as his speech, but he seemed unaware of the problem.

After a rest of four months he recovered, but he had another attack six weeks later that left him unable to speak, write, or understand music. He died soon after and the autopsy showed an intact left hemisphere, a bloody swelling of the right corpus striatum, and lesions of the right insula.

Charcot, 1883 (A) (cited by Bernard, 1889; Edgren, 1895; Ballet, 1898; Ingegnieros, 1906; Dorgeuille, 1966). A professor who was a distinguished musician discovered one day to his surprise that he was unable to read music at the keyboard, although he could play without difficulty. He later developed a right hemiplegia and aphasia and died from the disorder.

Charcot, 1883 (B) (cited by Edgren, 1895; Ingegnieros, 1906; Dorgeuille, 1966) A 45 year old professional trombonist and music copyist discovered that he was no longer able to copy music adequately. His hand still moved normally, he knew what he wanted to write, and he was able to write text normally, but he could not copy the music properly. Similarly, he found that he was unable to play his trombone correctly; although he knew what notes he wanted to produce, he was unable to move his hands and lips appropriately. These were the first signs of his progressive neurosyphilis.

Brazier, 1892 (cited by Edgren, 1895; Dupre & Nathan, 1911). A 36 year old music teacher tried to play the piano from memory after a day-long migraine. Her playing was so bad that she took out the score, but found that she was completely unable to read it. The next day her vision was tested and found to be normal. She was able to read text and numbers normally but not music. She could sing and play from memory and recognized music she heard normally. On the third day she could read the duration of the notes but not their pitches, and on the fifth day she had recovered completely.

Comment--Ingegnieros (1906) considered this to be a

case of hysterical amusia.

Wuertzen (1903) reported the case of a 48 year old man who had a stroke giving him a complete, transient left hemiplegia and persistent left hemianesthesia. He was admitted to a psychiatric hospital with a diagnosis of "Exaltatio mentis." On examination he showed a residual left facial weakness and difficulty swallowing. His speech was normal, although it had been unclear immediately after his stroke. The patient reported that his rhythmic sense was completely defective and that he found he was unable to find the strings on his violin with his left hand. Ten years later he was examined again. He was unable to sing and his whistling was very poor. He was also very poor at recognizing music and he was unable to detect wrong notes. He was unable to repeat tapped rhythms and he was poor at following the rhythms of music in dancing. In spite of this he still greatly enjoyed listening to music. He also tried to relearn the violin. He was able to read the notes easily (how this was determined is not stated) but he could not find the notes with his left hand, and he was unaware of his errors.

Jossmann (1927) reported the case of a 29 year old teacher, violinist, and singer with excellent sight-singing capacities who had an aneurism removed from the bifurcation of the right internal and external carotid arteries. He awoke with a left hemiplegia and speech which was hindered by his facial paresis. He had no difficulty swallowing. The hemiplegia cleared, and within a few months his colleagues had noticed that he sang poorly. He was unable to sing songs correctly, to repeat melodies or to whistle. He was examined a year after surgery and showed mild weakness in his left face and hand, slight incoordination on the left and decreased sensation on the left. He could distinguish high and low tones, major and minor chords, consonant and dissonant chords, and loud and soft tones. He identified singing, whistling, violin, and piano. He recognized simple tapped rhythms and waltz, march and polka meters and tempos. He was able to identify about half of the familiar melodies presented to him and seemed to do better when harmony was present. He showed difficulty starting when attempting to sing or whistle. He matched pitches accurately, but was inconsistent in his attempts to sing back chords played on the piano. He sang with correct rhythm, but he made several errors of pitch, especially for large intervals. He was able to identify the correct time and pitch values for written notes, but he was only able to identify a familiar tune from its notation on the basis of its rhythm. He wrote notes with their correct pitch and time values. He played the first five notes of a scale correctly on the violin but then made errors. He played a familiar melody better by ear than by reading it from the page.

Dorgueille, 1966 (B) (Case 12). A 61 year old right-handed woman with family history of left-handedness had a history of singing in a church choir with good sight-singing abilities, and a year or two of piano lessons. She had a thrombotic stroke to the right hemisphere giving her a left hemiplegia which cleared and other symptoms described below. She was examined three years later. She showed left hyper-reflexia and a left sensory loss. Her speech was very anomic, but she had good comprehension. She read well, but her writing was very limited. Calculations were difficult. She had difficulties with drawing and other visual-perceptual material.

She sang with good rhythm but bad intonation. She was unable to match pitches, but identified her errors. She was able to recognize melodies, instruments, and styles, but failed to identify errors. She was unable to read music. In copying music she got the rhythm correct, but put the notes on the wrong lines.

4. Theories

Ballet (1886) advanced the theory that capacities are lost as a consequence of brain damage in the reverse order in which they are acquired. He therefore predicted that disorders of music reading would always precede or accompany disorders of language reading, since musical literacy is acquired after verbal literacy. He cited the cases of Charcot (1883a&b), Finkelnburg (1870), and Proust (1866) in support of this view.

Probst (1899) reviewed four cases of "note-blindness." Three of these cases were aphasic and had large lesions and one (Finkelnburg, 1870) had a right hemisphere lesion. Nevertheless, Probst concluded that "note-blindness" is localized near "word-blindness" near the left angular gyrus.

Henschen (1920) reviewed all of the cases of amusia reported in the world's literature as part of his review of all reported cases of aphasia. He compiled 43 cases in which music reading had been examined of which 27 were in his judgment "note-blind." By comparing these 43 on other abilities he observed that "note-blindness" was independent of "word-blindness," "word-deafness," "music-deafness," "avocalia" (inability to sing), "word-agraphia," "note-agraphia," and "instrumental amusia." He noted that there were no cases of "acopia" (inability to copy) with preserved music reading. He concluded that music reading must therefore have an independent cortical center. He observed, however, that "note-blindness" tends to be associated with "word-blindness" and with "note-agraphia," and that "note-agraphia" tends to be associated with "word-agraphia."

He concluded on the basis of 6 autopsied cases that the center for music reading was probably in the vicinity of the left interparietal fissure near the center for word reading, but that the evidence on this point was not good. He suggested, largely on the basis of Brazier's (1892) questionable case, that "note-blindness" might have several components, such as pitch and time values.

Feuchtwanger (1930) reviewed Henschen's work. He noted that of the 23 cases showing disorders of music reading or writing, 5 showed impairment of both, 11 showed impairment of reading only, and 7 showed impairment of writing only. He observed that those showing a disturbance of both functions were also aphasic (eg. Fischer's (1863) case) and their other musical functions were not well examined. He attributed their music reading-writing disorder to a more general acoustic-musical impairment. He also claimed that some of the cases of reading disturbance only (e.g., Wurtzen's (1903) case) were due to an acoustic-musical disturbance, and that some of the others (e.g., Jossmann's (1926) case) were due to an expressive amusia that made it impossible for the patient to sing a melody internally and thus recognize it from the printed page. Other cases he attributed to true visual disturbances and to disturbances in visual symbol-function or alexia.

Feuchtwanger summarized by outlining the following six types of disturbances that he claimed could result in disorders of music reading:

a) Apperceptive visual agnosia. The notation cannot be correctly perceived. The perception of visual Gestalts, and in many cases also colors, is disturbed. Only perception is destroyed, not visual ideas, and in uncomplicated cases musical notes can be written.

b) Associative visual agnosia. The notation can be perceived and conceived of, but no longer with the property of representing notes. The writing of music is also destroyed.

c) Total sensory amusia and aphasia. The well-recognized notation system has lost its connection because its signification is no longer adequate. Only auditory perception is disturbed, not the expression of auditory ideas, so note-reading is preserved.

d) Expressive amusia. Reading aloud is impaired because of the expressive difficulty, and reading silently is probably also disturbed because it requires internal construction of the music.

e) Destruction of acoustic symbol-function, either secondarily as a disturbance of the connection between sound and idea (transcortical disturbance) or primarily as a true acoustic symbol disturbance (sound-name amnesia). Note-reading is destroyed in the unskilled, because for them the

acoustic idea is always tied to the name of the sound.

f) Destruction of visual symbol function (True alexia-agraphia). Visual and auditory ideas remain and the idea that there is a connection between them is intact. Only the symbol connection between them is destroyed. Note reading and writing are destroyed in parallel with disturbances of language reading and writing.

5. Evaluation of Case Histories

The general quality of the case literature in this area is clearly quite poor. There are relatively few cases available in which music reading has been evaluated. Most of those cases are very poorly described. In particular, what passes for music reading varies widely from case to case. Tests that have been applied include naming notes, pointing to symbols named, recognizing melodies from their notation, sight-singing, sight-reading on an instrument, reading familiar music on an instrument, identifying errors in the examiner's playing, and even writing or copying music. Most often only a single test has been applied and it has been presumed (either by the authors or their reviewers) to test all of music reading. In some cases the authors apply no tests at all and never observe the patient trying to read music but report only that the patient reported difficulty. Still other authors note only that music reading was preserved or impaired without mentioning how this was determined.

Most authors also fail to take an adequate history of training, skills, and habits in music reading. For instance, Jellinek (1956), after careful testing, reported an astonishingly complete musical alexia, yet never presented evidence that her patient had had the ability to read music premorbidly. Given the great individual differences in these factors as described above, such a history is a prerequisite to an adequate understanding of each case. Many authors, especially the early ones, failed to give adequate tests of other musical functions and even of language functions.

Despite the many inadequacies of these case reports, several tentative patterns can be discerned. First, it is easy to agree with Feuchtwanger's (1930) general conclusion that many different types of disorders can result in impairments in at least some aspects of music reading. But as Ustvedt (1930) and Benton (1977) have remarked, it is difficult to accept Feuchtwanger's excessively theoretical and empirically unfounded classifications of musical alexias.

Second, it appears that Benton (1977) was correct in concluding that no convincing cases of isolated disturbances in music reading have been reported. Those cases in which musical alexia is not accompanied by verbal alexia seem

attributable to a more general musical disturbance, or else the phenomenon was transient and poorly examined and described. Nevertheless, the possibility of such a syndrome is not to be ruled out. Even with a very high literacy rate posterior alexia is a rare syndrome. If, for instance, a posterior musical alexia were to result from the combination of a splenial and a right occipital lesion we might be unlikely to see it, given the rarity of such lesions, the low musical literacy rate, and the small likelihood that the affected individual would seek medical attention or receive neurological recognition. It may be that Proust's (1866) was the only such case in modern medical history, although the report is much too sketchy.

Third, Benson and Geschwind (1969) appear to have been correct in concluding that in most cases of posterior alexia music reading is also disturbed. There have been two exceptions reported. In Casey and Ettlinger's (1960) case, the preserved music reading consisted of applying a rhyme to the positions of notes on the staff, and reading rhythms that he had just written in idiosyncratic notation. The former test is akin to an ability to count lines, while the latter is confounded by the memory of what he had just heard and written, and is in any case questionably related to the reading of musical staff notation as reported in all other cases. In Assal and Hadj-Djilani's (1976) case the method of testing is not described. The lesion in this case was apparently a hematoma underlying the angular gyrus; thus the more extensive lesion and hemianopsia usually found in posterior alexia was not present. Again, however, caution is in order. The music-reading backgrounds of the patients described are unimpressive or poorly described and the testing is inadequate. Posterior alexia, musical literacy and adequate testing are all rare and the appropriate co-occurrence of these factors may not have yet come about.

Fourth, despite more than another half-century of accumulated cases, there is still inadequate evidence to support the localizations of Probst (1899) and Henschen (1920). Their conclusion, that "note-blindness" results from lesions in or near the left angular gyrus, was reached by the highly questionable method of searching for the common lesion in a set of patients with a common symptom. The persistent association of musical alexia with posterior alexia tends to support their position, but an examination of music reading in a patient with a circumscribed angular gyrus lesion has not yet been reported. If anything, Assal and Hadj-Djilani's (1976) case tends to disconfirm their conjecture.

Fifth, it is necessary to disagree with Ballet's (1886) prediction that a music reading disturbance would always precede and/or accompany a language reading disturbance. It

appears instead that music reading can often be preserved in the face of a language reading disturbance if there is a more general language disturbance present. This is especially true if the music reading task does not involve a verbal component, such as naming the symbols or notes.

E. RATIONALE OF THE PRESENT STUDY

The case presented here is that of a composer with a posterior alexia. In examining him we have attempted to avoid some of the procedural limitations of earlier studies, and to determine the effects of his illness on several different forms of music reading behavior. In addition, we have used his music reading behavior as a tool to help discriminate among general hypotheses concerning the nature of alexic disorders. For instance, contemporary theorizing suggests that his deficits might be due to any of the following hypothetical deficits:

1) A visual-perceptual disorder
2) A visual symbol recognition disorder
3) A visual-verbal disconnection
4) A disconnection of visual input from portions of the left hemisphere concerned with processing sequential material.
5) A disconnection of visual input from areas responsible for "pure" visual-auditory associations
6) A disconnection of visual input from areas responsible for skilled fine motor performance.

II. CASE HISTORY

A. HISTORY OF THE PRESENT ILLNESS

B.L. is a 77 year old, right-handed composer-conductor and retired professor of music in previously excellent health who was conducting an orchestra when he felt as if he had been "hit in the head". The next morning he was noted to be confused with unintelligible speech and faltering gait. He was admitted to the hospital that day.

B. NEUROLOGIC EXAMINATION

The patient showed a right homonymous hemianopsia, confirmed by kinetic perimetry, and moderate shrinkage of the intact visual field compared to age-matched controls. Flicker perimetry showed nearly normal flicker fusion frequencies in the intact left visual fields. Corrected visual acuity was 1/5 normal at 2 feet viewing distance. The optic discs were normal. The range of eye movements was full. Optokinetic nystagmus was markedly diminished with targets going to the patient's left. There was slight right facial weakness, but limb strength was normal. Somatic sensation was also normal. Reflexes were slightly exaggerated on the right and there was a positive right Babinski sign.

Lumbar puncture revealed yellow-pink cerebro-spinal

fluid. Skull X-rays were normal. Computerized transaxial tomography four days after admission showed an area of increased density consistent with a left occipito-temporal hematoma (Figure 1). Electroencephalography showed shifting and generalized slowing, more abundant and of lower amplitude on the left.

C. LANGUAGE EXAMINATION

Data on the course of B.L.'s language disorders come from his neurologist who followed him during the course of his two-week hospitalization and who saw him at four weeks and 3 months post-onset, and from his speech pathologist who performed evaluations four days and also two weeks after admission. The patient's scores on the Boston Diagnostic Aphasia Examination (BDAE) (Goodglass & Kaplan, 1972) from these two evaluations are given in Figure 2.

1. Speech

The patient was alert. He showed marked word-finding difficulty and frustration. His responses were slow and purposeful complete grammatical sentences. Articulation was unimpaired except for occasional stutters at the beginnings of words. He responded positively to phonetic cueing. His speech showed literal and verbal paraphasias which were frequently self-corrected. In the following weeks his errors became less frequent and his sentences became longer, but his speech retained the characteristics described.

He was able to name some objects presented visually and to recognize the names of famous persons whose pictures were presented. Color naming was more difficult. He was able to name a few objects from their descriptions. At two weeks he was able to name most letters and geometric forms tested, but not pictures of objects or actions. Color and number naming was difficult but possible. He was able to name most objects described. At 4 weeks he named 7 out of 8 colors correctly, calling bright red "orange".

Singing and rhythm tapping were intact, but he was unable to recite nursery rhymes.

2. Auditory Comprehension

On admission he was unable to perform one-step verbal commands, but he repeated them clearly and puzzlingly as though trying to ascertain their meaning and made comments such as, "Let me see, how would you do it?" Repetition was good for words and short sentences, but he produced verbal paraphasias on longer material.

Three days later he could follow a two-step command but was unable to answer correctly questions such as, "Is a hammer good for cutting wood?" He showed better comprehension of paragraph-length material, suggesting that his auditory comprehension was improved by redundancy. At two weeks he was able to follow a five-step command and sentence comprehension had improved significantly. He was able to

30.

FIGURE 1. COMPUTERIZED TOMOGRAPHY SCAN OF B.L.

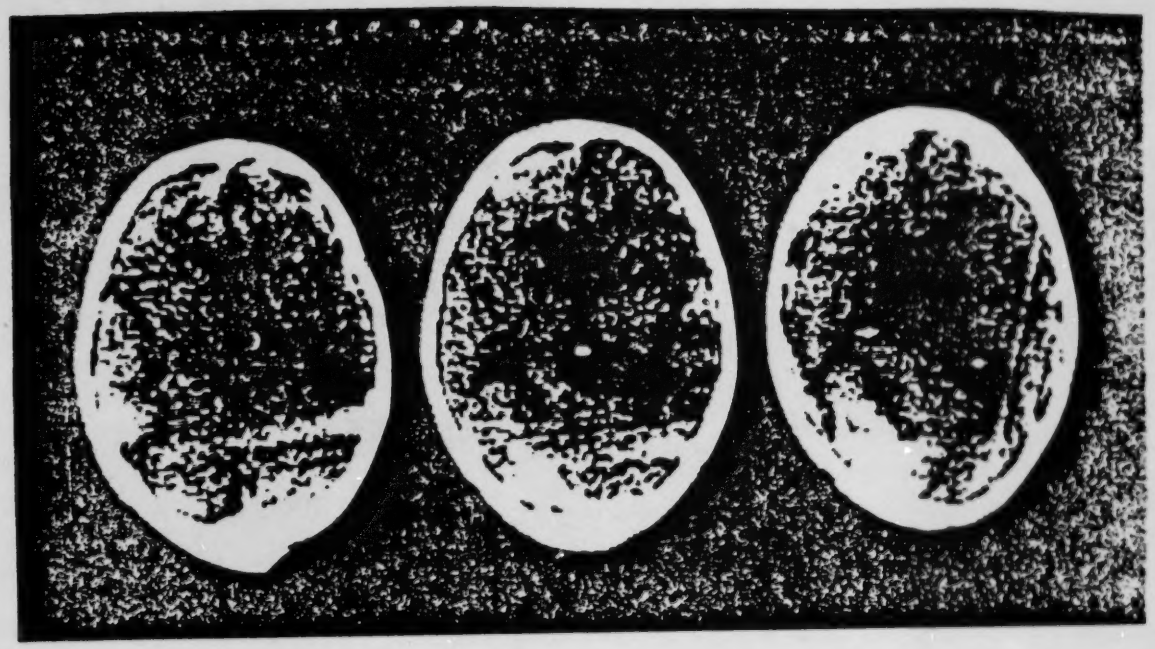
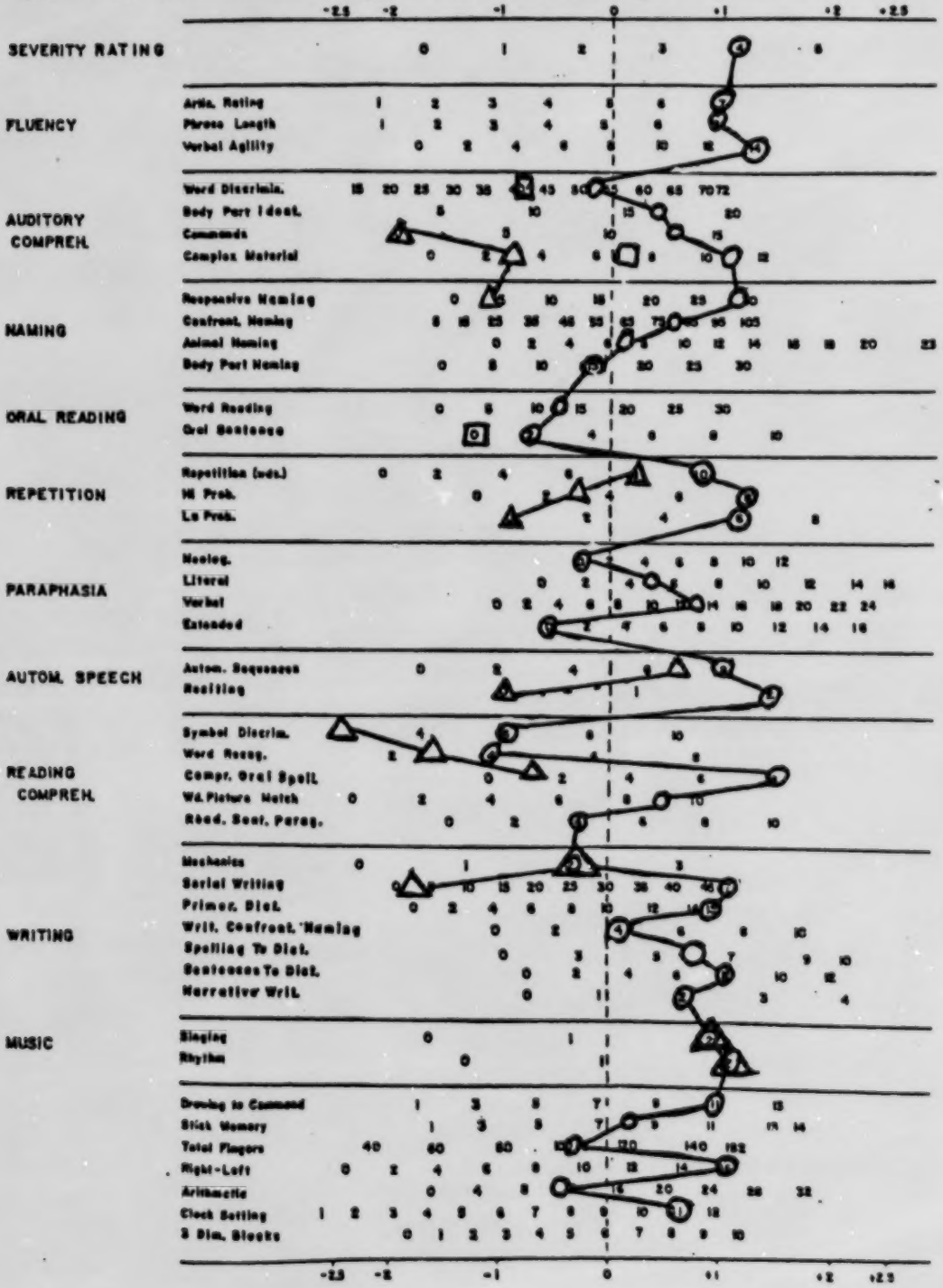


FIGURE 2. BOSTON DIAGNOSTIC APHASIA EXAMINATION SCORES FOR B. L.
Compared to Z-scores from 207 aphasics (Goodglass & Kaplan, 1972)
△3-6 days post-stroke □2 weeks post-stroke ○14-16 months post-stroke



repeat moderately difficult sentences. At four weeks he could repeat 5 digits forwards and he could repeat 4 nonsense syllables. He could point to body parts including fingers and showed no right-left confusion.

3. Reading

On admission he was unable to identify any letters or words. This difficulty persisted, especially for words. At four weeks he could identify 19 out of 20 letters accurately, although slowly, but his word identification was still very poor, even for three-letter words. This was unchanged at 3 months.

4. Writing

At three days the patient could write his name, but not his address or any numbers. He wrote only one letter correctly to dictation. At one week he was able to write his name and a sentence to dictation with poor handwriting and an occasional doubled or omitted letter. Copying print was nearly impossible. At 4 weeks he could write sentences spontaneously and to dictation. Copying handwriting was very difficult. He could recognize words spelled orally and he was able to spell difficult words orally.

In summary, the patient's initial symptoms were a moderate sensory aphasia and a dense right hemianopsia. The aphasia cleared rapidly except for a mild residual anomia and occasional paraphasias leaving him with the hemianopsia and a set of symptoms resembling the syndrome of alexia without agraphia, or posterior alexia.

D. OTHER INVESTIGATIONS

Beginning one month after his stroke, B.L. was a subject in an investigation by Levine and Calvanio (1978) (their subject R.T.). They investigated letter recognition and identification under tachistoscope conditions. B.L.'s duration threshold for single letter identification was only slightly longer than that of the normal controls. An aftercoming masking pattern impaired his single letter naming only slightly more than for normal subjects. Yet when he was presented with 3 letters he was usually unable to name all of them, even with exposure durations up to 5 seconds. He was successful in naming single pre- but not post-designated letters in an array of 3. He was better at naming the letters if they made an English word than if they did not, regardless of whether or not he was expecting a word. If he was only asked to say whether or not the three letters were identical his performance was better than for naming the letters. Besides omissions, his errors under all conditions were primarily morphological, in other words, he named letters which were similar in shape to the targets.

III. PRESENT INVESTIGATION

The present authors saw B.L. for 3 months beginning one year after his stroke, and again at 18, 24 and 30 months.

A. NEUROLOGIC STATUS

B.L.'s dense hemianopsia persisted and he complained of some double vision on downward gaze. Sensation, strength and reflexes were all normal.

B. NEUROPSYCHOLOGICAL EXAMINATION

The patient was fully awake and attentive, highly cooperative, and well aware of his difficulties. He reported that he had noticed a definite improvement in the past few months and had returned to composing. He complained of difficulty in searching for things and this was quite evident when he misplaced objects in his study. He showed a tendency to neglect things on his right. He fatigued noticably over the course of a few hours testing, so sessions were made frequent, informal, short and varied. He was slow at most tasks, but quite persistent and even perfectionistic. He displayed a sharp and cultured wit and was at all times highly appropriate and polite.

1. Wechsler Adult Intelligence Scale (WAIS)

The WAIS (Wechsler, 1955) was administered over a period of 2 months. Table 3 shows his scores. This includes the standard scaled score, an unofficial untimed scaled score derived by giving him credit for all items completed after the time limit, and the peer equivalent scaled score (from a group matched to the patient for age but not education). His high Verbal IQ reflects not only his high educational level, but also his lack of serious impairment from his aphasia. He showed a difficulty in dealing with numbers, which is reflected in his low Arithmetic score. This remained his lowest verbal subtest even when the time limit was eliminated. He complained that he was unable to retain the problems in his mind, and he asked many times for the problems to be repeated. This number difficulty was also reflected in his relatively low Digit Span score and in his performance on the Information subtest where 4 of his 7 errors were on items requiring numerical answers. Proverb interpretation was excellent. His Vocabulary performance was notable for occasional errors of auditory comprehension, for instance, he repeated "slice" as "slight," and "impale" as "impel."

His low Performance IQ is reflective of visual difficulties and slowed performance. He showed some difficulty in orienting to and keeping track of the stimuli. Nevertheless, he demonstrated remarkably good visual-constructive abilities when the time limits were ignored. For instance, he completed all of the Block Designs and all of the Object Assemblies correctly and only once required

TABLE 3. WECHSLER ADULT INTELLIGENCE SCALE SCORES FOR B. L.

Full Scale IQ: 98; Verbal IQ: 117; Performance IQ: 78

Untimed Performance IQ (prorated without Digit Symbol): 130

Test	Scaled Score	Untimed	Peer Equivalent (timed)
Information	13		15
Comprehension	10		14
Arithmetic	5	7	8
Similarities	9		12
Digit Span	9 (6f, 4b)		12
Vocabulary	15		16
Digit Symbol	0		0
Picture Completion	4	7	8
Block Design	4	12	8
Picture Arrangement	2	10	7
Object Assembly	6	9	10

more than twice the allotted time to do so (300 seconds on Block Design # 10). Extra time also helped him on Picture Arrangements, but here he took 6-10 minutes extra on each of the last five items that have only 1 or 2 minute time limits. His Picture Completion performance was notable for a failure to recognize some of the pictures and for frequent confusion of body parts (he said "ear" and "eye" for "nose", "nose" for "eye", "leg" for "arm", and "legs" for "fingers"). He was unable to do the Digit Symbol test because of difficulty reading, number confusions, and difficulties orienting to the task visually.

2. Wechsler Memory Scale

Table 4 shows the results of his performance on the Wechsler Memory Scale Form I (Wechsler, 1945). He showed a mild naming deficit on the Information subtest, difficulties dealing with numbers, and a mild to moderate impairment in learning new material. After a 20 minute delay, however, he showed good retention of the verbal material he had learned, but poor retention of the visual material.

3. Praxis

He responded promptly and appropriately to all requests to mime various activities. However, in attempting to imitate non-representational gestures performed by the examiner he sometimes used the wrong hand or the wrong finger.

4. Hooper Visual Organization Test

The Hooper (1957) Visual Organization Test consists of 30 pictures in which a line drawing of an object has been cut into 2-5 pieces like a jigsaw puzzle. The subject's task is to name the object. The patient got 24 correct, a very good performance for his age, but he took 90 minutes on the task while most subjects take less than 10 minutes. This slowness was due in part to a difficulty in visual search and a difficulty in word finding. His typical strategy was to identify the pieces and specify which edges would fit together.

5. Subjective Contours

Subjective contours are displays that create in the viewer the experience of perceiving a contour or form which is not actually present in the stimulus (Kanisza, 1976). Perceiving subjective contours most often involves integrating information from several free-standing figures on the page. Perception of these countours has been reported to be severely impaired in visual agnosia-simultanagnosia (Wapner, Judd & Gardner, 1978), a central disorder of visual perception involving alexia without agraphia and poor recognition of objects and scenes in the visual modality, especially complex scenes. The patient performed completely normally in identifying all of the

TABLE 4. WECHSLER MEMORY SCALE SCORES FOR B. L.

Memory Quotient: 89

Test	Raw Score/Total Possible		10 Minute Recall	Conv
Information	3/6			
Orientation	5/5			
Mental Control	5/9			
Memory Passages	7/23		5	
Digits Total	8	5f, 3b		
Visual Reproductions	7/14		2	11
Associate Learning	7/21			

subjective contours illustrated in an article by Kanisza (1976).

6. Boston Diagnostic Aphasia Examination (BDAE) Supplementary Tests

Figure 2 (above) shows his scores on the BDAE Supplementary Tests (Goodglass & Kaplan, 1972). He performed acceptably for his age on drawing to command. He drew good likenesses of a clock, a daisy, a red cross, and a cube in perspective, but his house and elephant got entangled in details (Figure 3). He copied them acceptably. He was able to reproduce stick designs from immediate memory well for his age. He performed normally on right-left orientation, clock-setting and pointing to named locations on a map. He showed moderate impairments on all verbal and non-verbal modes of finger gnosis testing. On inquiry he noted that he sometimes made small errors in playing the wrong chord or putting his hands, especially the right hand, at the wrong place on the piano until he got used to it. He performed poorly on written arithmetic. His best performance was adding 3 two-digit numbers correctly although very slowly and with many self-corrected errors in reading the numbers aloud. He did only a few subtraction and division problems correctly and he was unable to multiply. Orally he was only able to do single digit calculations.

C. NEUROLINGUISTIC EXAMINATION

1. Boston Diagnostic Aphasia Examination

Figure 2 (above) presents his performance on the BDAE (Goodglass & Kaplan, 1972) as reported by his speech pathologist at one week and at two weeks post-stroke, and as measured by the present authors at 14-16 months post-stroke. The earlier evaluations were discussed above. On this examination his spontaneous speech was fluent but mildly paraphasic and circumlocutory. He observed, "I substitute devious explanations for what I want to say." His repetition was entirely within normal limits. Auditory comprehension was mildly impaired. He failed four items in a test of pointing to named pictures and he was slow on several others. He also failed several items on a body-part identification test when he pointed to his hip instead of his thigh, his wrist instead of his elbow, and his eyelid instead of his eybrow. He performed better with more complex comprehension material, apparently benefiting from the redundancy.

He was quite good at naming objects from their descriptions. When asked to name pictures of objects he was slower and made several verbal paraphasias (semantic confusions) and possibly perceptual errors such as calling the chair a shoe. Color naming was good. He made frequent verbal paraphasias in trying to name body parts. Other

FIGURE 3. DRAWINGS OF A HOUSE BY B. L.

(Reduced from original by 25%)

Drawing to command

Copy

Model

Copy

results on the BDAE are described above and below.

2. Reading

He was severely impaired at all levels of reading. Of the various reading skills tested, he was best at comprehension of oral spelling and at letter reading. For instance, he got all 8 of the Comprehension of Oral Spelling items on the BDAE correct which includes difficult words like "whiskey." He named 27 out of 33 upper and lower case isolated letters scattered on a page correctly in 300 seconds. On the Visual Confrontation Naming Test of the BDAE, he named all 6 of the letters presented correctly within 3 seconds each. In this test the letters are presented in relative isolation (i.e., they are not close enough to one another to suggest a word configuration), and other naming items intervene between the letter-naming items. But in attempting to point to the same letters from their orally-presented names he made two errors, and his first initial was the only letter he pointed to correctly in less than 5 seconds.

Despite his good performances on these tests, he was unable to put these skills together to produce adequate word reading. He was able to recognize a few words without analysis, especially shorter ones and words attempted at the beginning of his reading efforts. But when this failed his strategy in word reading was to name each letter, tracing with his finger those that he had trouble recognizing. He would then try to recognize the word from its oral spelling. In this he would frequently fail, either because he had misidentified some of the letters, or because it had taken him so long to name them all that he forgot some of them. For instance, in trying to read "HAMMOCK" he spelled "H-A-R-R-O-C-H" and only got the word correct after a second try, taking 20 seconds all together. He read "DRIPPING" as "D-R-I-F . . . driving?" and finally got it correct after 35 seconds.

He was unable to match short words and letters to their equivalents in other English alphabets, i.e., upper and lower case and cursive. His errors suggested visual confusions: "B" and "d," "dog" and "BOY," "pal" and "gal [cursive]." He showed other apparently visual confusions in pointing to words from their oral names when he pointed to "shop" for "ship," "beer" for "book," "whip" for "with," and "bunny" for "puppy." He was unable to match words to pictures without reading aloud.

When he attempted to read connected words the above patterns were present, but he also showed perseveration and contextual guessing. This is illustrated in the following transcription (the stimulus sentences are presented in brackets): [You know how.] "You know how." [Down to earth.] "How to eat . . . How to earn. . . . Down to

earth." [I got home from work.] "I do . . . I dot . . . I have hope for . . . from . . . I hop down from work." [Near the table in the dining room.] "Fear the table in the dining room. . . . F-E-A-R" [They heard him speak on the radio last night.] "She feared him . . . She heard him speaking of him in the reading room." [Limes are sour.] "L-I-M-E-D . . . something to do with soup. Lines are after soup. S-O-U-P soup." This session took approximately 10 minutes.

He neither reported nor displayed any evidence of extracting any semantic content from written words without being able to read them aloud. He could not categorize written words semantically nor answer questions about their meaning without reading them aloud.

His number reading was worse than his letter reading. He showed considerable number confusion, especially for 5, 6, 7, and 9.

He was very distressed by his reading disorder and practiced reading daily in an attempt to recover. He wore mild magnifying lenses over his trifocals when attempting all reading and writing whether of language, numbers, music or pictures. His claim that larger letters and notes were easier for him to read appeared true, and large letters and notes were used in testing whenever possible.

3. Writing

His handwriting was painstakingly slow and showed occasional distortions, substitutions, omissions and doubling of letters. It was for the most part legible, however. Except for these errors he could write whatever was requested of him including the alphabet, the numbers, the names of pictured objects, descriptions of pictures, and letters, words and sentences to dictation. The results of his attempts to copy were similar to his spontaneous and dictation writing except that he showed some of the contextual guessing and perseveration typical of his attempts to read prose. For instance, he copied "She wears a rose in her hair," as "She weals a wose in her heart" (Figure 6, below).

When he attempted to write longer material, such as familiar poetry or a letter, he ran into more problems. His own poorly-formed letters were especially difficult for him to read; consequently he was effectively unable to refer back to what he had written. This was compounded by his impaired verbal memory. He sometimes omitted or substituted entire words and occasionally abandoned sentences half-way through or completed them improperly. Nevertheless, he used a cultured vocabulary and displayed good planning and an adept use of wit and figures of speech. For instance, we asked him to write a letter describing our work together. He took several weeks on this effort, starting with an

outline he was later unable to read or use. Finally, he abandoned this approach and wrote a two-page letter in two hours, the first page of which is reproduced in Figure 4. He described the experience as "overwhelming and even depressing."

D. NEUROMUSICOLOGICAL EXAMINATION

1. Background

Before his stroke the patient's vocal, keyboard and conducting capacities were adequate for the purposes of teaching and composing, but his public performance attainments in these areas were modest compared to his reputation as a composer. The most significant of his public activities was his habit of conducting concerts primarily of his own works. He enjoys an international reputation as a composer, primarily of choral works and entirely in the tonal system with a very lyrical style. He was in the habit of composing with frequent reference to the keyboard and often improvised for his own enjoyment, yet much of the compositional process also took place away from the keyboard. For instance, he composed at the blackboard in front of his classes. He had an intimate knowledge of tonal theory. He was completely literate in music. He was an experienced proof-reader, could sight-sing, he could sight-read at the piano, and he could read a score "hearing it in his head." He did not possess absolute pitch.

2. Critical Perception

To our examination, his perception of music seemed quite intact. His pitch discrimination was very good, he was able to detect slight changes in tempo and he was able to detect errors of performance. He criticized with great sensitivity a tape of a performance of one of his works, commenting on the tempo, the note attacks, the dynamics, the tone quality, the intonation, and the overall emotional interpretation. He resumed rehearsing and conducting performances of his own works beginning one year after his stroke, reportedly quite successfully.

3. Production

There was no definitive evidence that singing was impaired. In singing familiar songs, his pitch and rhythm were intact and he was able to sing with good musical expression, but there was a poor quality to his voice, especially in the lower register. This difficulty may have been premorbid (he had once been rejected from a college choir) or a result of a lack of practice. He showed no hesitation in expressing his musical ideas vocally, nor were errors apparent.

His piano playing was slowed and he complained of displacing his hands a note or two on occasion. Though scales and exercises were performed adequately, there was

FIGURE 4. LETTER WRITTEN BY B. L.

This first page of the letter (see next page) was written in about one hour. The figure is reduced from the original by 25%. It was written on lined paper (the lines did not reproduce). Here is a transcript of the letter:

Postscript:

I had gone about as far as this when I began to feel quite overcome by the difficulty of my proposed plan.

My plan was to emphasize the aspects of our work that we had pursued in reading and writing.

The work was simple, and no pressure was put on me to perform any complicated or difficult exercises. Yet I found the whole assignment was difficult and taxing. 1) In [?] of sentences led to my losing my way befor a sentence was completed; 2) I could not see all where I had begun continued or end a sentence; 3) I could not form on letters or phrases; my double and double vision came and went. 4) Fatigue slowed me down, and resting helped but only a little and briefly.

I reluctantly decided that the game was not worth the candle: my only was to discard my formal effort and to jot down a few observations. I could do so without straining my memory and without straining my my eyes or my memory.

FIGURE 4. (Continued)

Handwritten:

(a)

I had gone about as far as this when I began to feel quite overcome by the difficulty of my proposed plan.

The
[illegible] plan[illegible] to emphasize the aspects of and work that we had [illegible]
[illegible] concerned in reading and writing.

The work was simple, and no process was [illegible] me to perform any complicated or difficult exercises. But I found the whole assignment very difficult and tasking. 1) In [illegible] of sentences and [illegible] my losing me mean before a sentence was completed; 2) I could not remember where I had begun [illegible] or end a sentence; 3) It could not focus on letters or phrases; my [illegible] doubled and double: village came & went. 4) Fatigue slowed me down, and resting helped but only a little and briefly. I reluctantly decided that the game was not worth the candle: my only was to discard my formal effort and to jot down a few observations [illegible] straining [illegible] my memory and whether straining me

my eyes or [illegible] my memory.

often some groping for keys. On easy familiar material he was able to play correctly and expressively, but when given more difficult familiar material he was slowed considerably and made many errors. By his own judgment this was significantly below his pre-stroke performance level. However, he played very little for the six months following his stroke, and part of his difficulties may be attributable to lack of practice. His performance improved as we followed him, and he played quite a bit during that time.

He was generally able to convey a musical intention as he played. He would often omit less important lines and chords in order to maintain a musical continuity. On the other hand, in playing by ear very conventional or familiar music, he was sometimes able to improvise characteristic harmonies, ornaments and internal lines. When asked to perform a free improvisation he was at first reluctant, but performed appropriately and creatively with few errors and a good sense of form, although he played necessarily at a slow tempo.

4. Reading

The patient showed considerable facility with music reading and was able to use this skill effectively in a wide variety of contexts. He was able to read scores at the piano for pleasure, to read and work on the scores of his works in progress, to check proofs from his publisher, to read (without playing) and comment on the scores of student composers, and to search for, to find and to play specific excerpts from his library. However, he showed significant music reading difficulties in these and other contexts. He was unreliable at naming various musical symbols, he was poor at sight-reading unfamiliar, unmusical material such as sight-reading exercises, he tended to lose his place and to omit notes from the right side of the page, and he made contextual guessing errors.

Throughout our examination period he recognized familiar pieces of music quite readily and rapidly from the printed score even when the words were covered up. For instance, on the California Diagnostic Test of Music Achievement, Test # 10 (California Test Bureau, 1950) he recognized and named 18 out of 20 familiar melodies from the first four bars of their notation alone in 11 minutes. Most of this time was taken up on a few items as he searched his memory for the name of the song after he had already demonstrated his recognition of the song by humming it past the four bars given. By contrast, he was unable to recognize most of the written titles of the songs with unlimited time.

At 16 months post-stroke he misnamed 16 out of 17 musical symbols presented randomly scattered on a page. His errors were mostly perseverations. He was able to point to

14 of those 17 correctly from their names presented orally, and he wrote 9 out of 10 of them correctly from their names, presented orally. He named 7 out of 14 musical symbols when they were presented within the context of a musical score, and pointed to 13 out of 14 of them correctly from their orally presented names. At 24 months post stroke he was given a page with musical symbols, letters and numbers mixed up on it. He named 12 out of 13 letters, 11 out of 15 musical symbols and 6 out of 13 numbers correctly.

At 36 months post-stroke we gave him a test to compare his note and letter reading under a variety of stimulus and task conditions. The music notation stimuli consisted of musical quarter notes ranging from "e" to "d" in the treble clef. There were no accidentals. Thus, seven notes were used which had letter names of A through G, and all of the notes appeared in the seven middle spaces and lines of the clef. The letter stimuli consisted of uppercase printed letters from A to G. The letters and the musical staves were both 1 cm. high. There were four stimulus conditions with letters or notes in either a vertical or a horizontal arrangement. In the vertical arrangement conditions the items were presented in a column and successive items were separated by a space of 3.5 cm. In the horizontal arrangement conditions the seven items of a trial block were presented on a single line occupying 6 cm. all together, thus appearing like typical words or melodies.

The subject's tasks were either to name the letter or the note or to play the appropriate key on the piano. The four stimulus conditions and the two response conditions generated 8 conditions in all. There were 7 items in a trial block and 3 trial blocks per condition making 21 items per condition. Each trial block contained all 7 letters or notes in a pseudo-randomized order. Trial blocks were alternated between letters and notes for otherwise equivalent conditions, and there was a 5 minute break half-way through. The order of conditions was as presented in Table 5. The control subject was matched for education and occupation but not age.

The results are presented in Table 5. After the test was over the condition of playing horizontally-presented letters was repeated since he had performed so poorly on that condition. These results also appear in Table 5. His errors were either omissions or they seemed to be visual confusions. For instance, all of his note-reading errors regardless of condition were wrong by a musical third. This suggests that he was able to recognize whether the note was on a space and not a line, for example, but he made mistakes as to which space.

When asked to comment on the tasks he said that the horizontally arranged letters were the most difficult to

TABLE 5. LETTER AND NOTE NAMING AND PLAYING TASK:

RESULTS FOR B. L. AND CONTROL SUBJECT

Condition	Subject			
	B. L.		Control	
	Time (seconds)	Errors	Time (seconds)	Errors
Naming Vertically-Presented Letters	25	0	8	0
Naming Vertically-Presented Notes	26	1	15	2
Playing Horizontally-Presented Notes	27	1	7	0
Playing Horizontally-Presented Letters	525	15	9	0
Naming Horizontally-Presented Letters	41	0	8	2
Naming Horizontally-Presented Notes	41	5	9	0
Playing Vertically-Presented Notes	63	3	9	0
Playing Vertically-Presented Letters	170	8	10	0
Playing Horizontally-Presented Letters	97	5		

read because they were confusing, but the horizontally arranged notes were the easiest to read, because it was possible to tell what each note was from its relation to the previous note as well as from its position on the staff. He also said that it was difficult to play a note from its letter name because that was an uncommon task.

He frequently got lost by falling behind when attempting to follow the score of a piece of music being performed even if it was something quite familiar, such as something that he had just composed. When he did follow the score, he was often able to pick out errors of performance. He chose to conduct his concerts without the score for fear he would lose his place.

In playing the piano he preferred playing from a score to playing by ear, the only exception to this being some parts of works in progress. His playing was slow and effortful and there were frequent mistakes which were generally self-corrected. He was nonetheless often able to maintain a tempo while playing a melody with its harmonization and was sometimes able to play two- and three-part music. Due to his right hemianopsia and neglect he had a tendency to omit the last few notes on a line which he often discovered when he started the new line. He occasionally lost his place on the page especially when he found it necessary to look at his hands for a moment while playing.

No particular aspect of the reading or playing gave him special difficulties--he was able to read melody lines, chords, and rhythms accurately and the coordination of separate contrapuntal lines was accomplished automatically--but the complexity of the task slowed him down, and as a consequence the rhythm often suffered. In fact, an element of "faking"--in the best sense of the word--went into his reading music at the keyboard. When confronted with a difficult piece he would sometimes omit the less important inner voices in an attempt to maintain the flow, he might anticipate a chord without actually reading, or he might regularize a rhythm or a melody. In addition, when playing his own compositions he would sometimes make errors which suggested that he was using his memory of the composition as a supplement to his reading. For instance, in playing his recent composition he sometimes played parts of the second verse when reading from the very similar music for the first verse. Thus, he seemed to rely heavily on the use of the musical context in reading as is to be expected for a skilled and knowledgeable reader.

His sight-reading of totally unfamiliar material exaggerated these tendencies. He was given the Belwin-Mills Sight-Singing Test (Bowles, 1971) and the Farnum String Scale (Farnum, 1969) (playing the violin score on the

piano). He responded to these improbable melodies by "regularizing" the rhythm and melody (Figure 5). He also showed another interesting pattern of errors on these tests. When he made an error of pitch he sometimes continued to play the next few notes transposed by the magnitude of the original error, suggesting that he was reading more on the basis of the relative intervals between successive notes than the absolute positions of the notes on the staff.

His approach to these tests made irregularities in administration necessary, but in general his performance compared poorly to that of the elementary school instrumental and vocal students on whom the tests were normalized. Thus he was significantly impaired in sight-reading compared to his premorbid abilities.

5. Writing

When the patient attempted his first post-stroke composition one year after the stroke he reportedly had great difficulties in getting it down on paper. His assistant related that at first they proceeded by dictation or virtually so, with the patient playing the music he wanted while she wrote it down. As they progressed, he became able to write down large portions of it himself, but these writings then had to be checked for accuracy. By the time the proofs arrived he was able to do much of the proof reading himself and without help corrected many errors and made improvements. He complained that he often failed to place his notes properly, for instance when he intended to place a note on a particular space it would often wind up on the adjacent line. We therefore supplied him with wide-lined staff paper, which was a significant help in this regard.

At 20 months post-stroke he wrote a 7 minute piece for chorus and orchestra in 5 weeks while on vacation with no assistance. He mailed in the score and the parts were copied directly from it for the first performance with no chance for consulting the composer. Only a dozen errors or so were found in the score, demonstrating that his music writing at this point was quite functional.

In copying the beginning of a song with its lyrics and its accompaniment (Figure 6) the patient encountered some mechanical difficulties. A slight tremor made his lines shaky and he frequently made mistakes of note placement as mentioned above. These were usually self-corrected. On one line he wrote the time signature as 6/8 instead of 6/4. His approach was systematic and line-by-line. He succeeded in getting the line properly aligned and the notes properly spaced. However, he made a few errors of placement when he filled in the phrase markings and crescendos. Copying the text gave him great difficulty and there were several errors in the final result despite many corrections, but it was

FIGURE 5. MUSIC SIGHT-READING BY B. L.

The first line is a transcription of the original stimulus from the Farnum String Scale (Farnum, 1969) Violin Exercise # 6. The second line is a transcription of his sight-reading of that exercise on the piano. The third line is a transcription of his sight-singing of that exercise one week later. Arrows in this line indicate the notes on which he reinforced himself with the piano. Boxes indicate errors. The octave transposition in the fourth and fifth bars was to accomodate his vocal range.

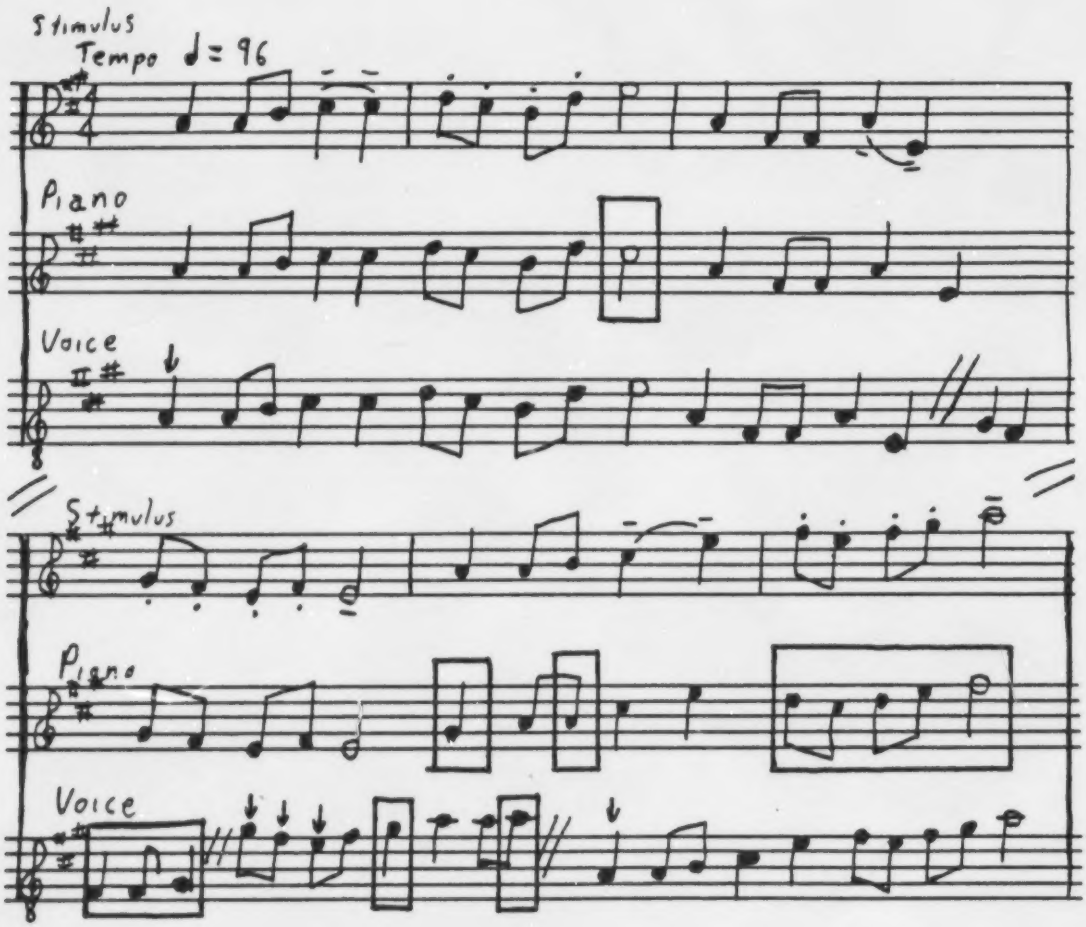



FIGURE 5. (Continued)

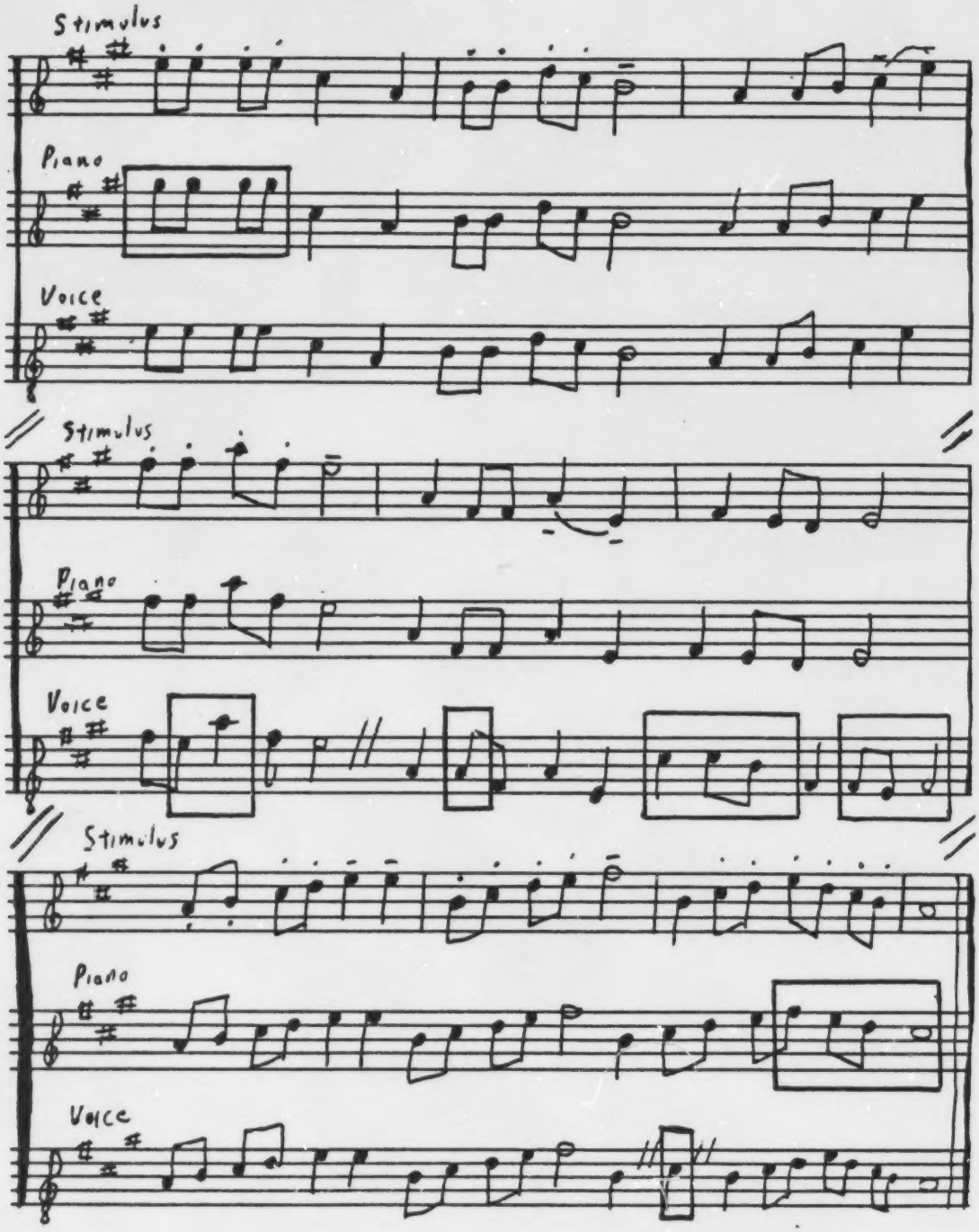
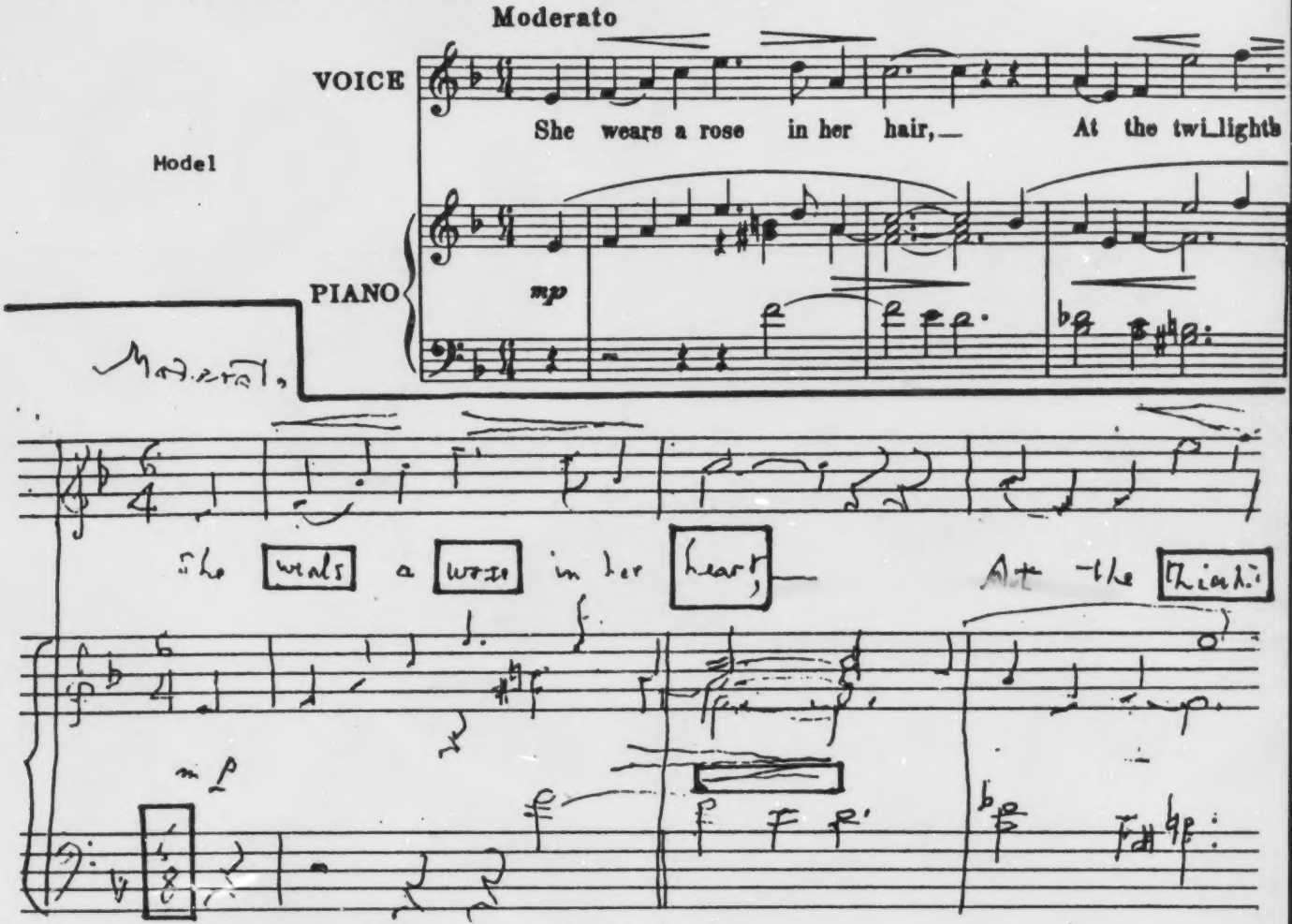



FIGURE 6. MUSIC COPYING BY B. L.
The copy is reduced by 25%. Boxes are drawn around his errors.

properly aligned with the music.

His performance on musical dictation tasks was surprisingly poor, especially considering the great facility with which he wrote down melodies he was composing. He wrote only one out of five short (3-5 note) melodies completely correctly, in spite of his request for up to four presentations of each. The rhythms were generally correct, but there were one or more errors of pitch on each of the failed items. Some of these may have been errors of placement as described above. When given a four bar, sixteen note melody, he requested 11 presentations, but the final result was correct except for three minor errors of omission. He wrote down four chords to dictation flawlessly, but he required three presentations of each. He made several errors in writing rhythms to dictation on longer items, especially when the barring was not obvious.

6. Memory

On several occasions he sang the dictation material incorrectly which suggested along with his requests for many repetitions that some of his errors may have been memory errors. This idea was confirmed by informal musical memory testing. On several occasions we sang a short melody to him and asked him to repeat it. Several repetitions of the model were generally necessary before he got it correct. When we asked him to recall the melody several minutes later he was unable to. By contrast, if we asked him to make up a short melody and sing it for us he was then able to repeat that melody immediately and several minutes later. The difference between these two conditions may account for the difference between his ability to write music spontaneously and to dictation. A mild impairment in antereograde musical memory is consonant with his mild antereograde memory impairment in other areas.

7. Composition

We were aided in the evaluation of his composition by Lyle Davidson, a composer and professor of music at New England Conservatory of Music, and by the patient's two assistants, one of whom is extremely well versed in the patient's life works and is himself a composer in a similar style. We gave the patient three composition exercises over the period of 14 to 16 months after his stroke. For the first we asked him to write a minuet in the style of Mozart, for the second we asked him to choose a theme from that minuet and write variations on it, and for the third we asked him to take one of the themes or variations and make a canon or other contrapuntal form from it (he wrote a fugue).

His approach to composition seems unchanged in spite of some adaptations in the mechanical process. Furthermore, he retains his motivation to compose, and his ability to achieve the proper mood for composing seems undiminished.

Following his stroke he was depressed about his verbal and visual difficulties and made little attempt to compose, in part because he was preoccupied with other life adjustments and in part because he was somewhat afraid to discover what difficulties he might encounter. However, an approaching commission deadline proved to be a sufficient stimulus to allow him to begin work on a composition one year after the stroke.

He began with careful and prolonged contemplation of the text (chosen before his stroke). A relative recorded the text on a tape recorder and he listened to it over and over (previous to the stroke he would have simply read or memorized the text). He chose the key modulations he wanted and on the basis of the dramatic thrust of the text, decided where he wanted a high note, where he wanted it to get quiet, what the final chord would be, and so on. He then decided on a rhythmic structure for the first line. He derived his themes by singing the words over in endless variations and choosing the variation he liked best. This process could take place in his head, through actual singing, or at the keyboard interchangeably, and at times he used each of these approaches. He said that he had absolutely no trouble generating new themes, and to illustrate he claimed at one point that he had generated three new variations on a plain song he was working on in his head during our previous two minutes of conversation. As the composition took shape, reference to the piano became more necessary. Largely because of the initial difficulty in writing, most of the composition was planned before it was on paper.

The compositional process described here is very similar to the process he described in his published notes on a piece he completed in the 1950s. The major differences are that he is much slower; he can no longer rely on reading his texts; the process of writing down the music proceeds especially slowly with many mistakes and requires frequent and multiple checks; and there may be a greater reliance on the keyboard because of the shortcomings in writing and memory.

He still very much enjoys composing. He reported that in working on our assignments he was "filled with amusement and high spirits." He gave very moving descriptions of the emotional significance of previous compositions as well as the events and feelings inspiring planned compositions. This left little doubt in our minds that the magnitude of this aspect of composing is unchanged for him, although the content may have changed somewhat with increasing maturity.

Judging the quality of the post-stroke compositions must to some extent await the test of time. He has stated that he thinks he could write better music now than he could

ten years ago. He has by now completed several post-stroke works on commission all of which were well received, and he continues to receive new commissions. These works and the exercises he wrote sound to us appropriate, subtle, well-constructed, cohesive and in fact beautiful. They seem quite consistent with his earlier style, but they are perhaps slightly less adventuresome than the works of the few years preceding his stroke. He is able to explain with eloquence his reasons for many of their features and with frequent reference to music theory, the art of composition and similar examples from his previous work.

On the other hand, the many impediments to composition described above may impose some limits on the quantity or scope of the patient's future output. He has not since his stroke attempted any work which even approaches the size and complexity of some of his previous masterpieces. In attempting the fugue for us his initial plan was to write a four voice fugue with a modulating theme as he had done in earlier compositions. He worked for several days and became discouraged and ashamed because he was unable to derive an appropriate subject which would work for such a fugue. He finally found an appropriate subject and realized that the problem was that he was just out of practice ("You have to be in practice, in condition to compose," he said). However, after some additional work he abandoned that subject and wrote instead a three voice fugue with a non-modulating subject because he realized that the project he had originally attempted would have been too long and complex and would have taken too much time for an exercise. Even so, it took three weeks for him to complete the fugue (Figure 7). By contrast, he had written such fugues in the past in front of his counterpoint classes at the blackboard. (Interestingly, he said he knew that his modulating subject would work and that it was completely invertable, as well, even though he had never played it through with the entrance of the second voice and he had not written it down.)

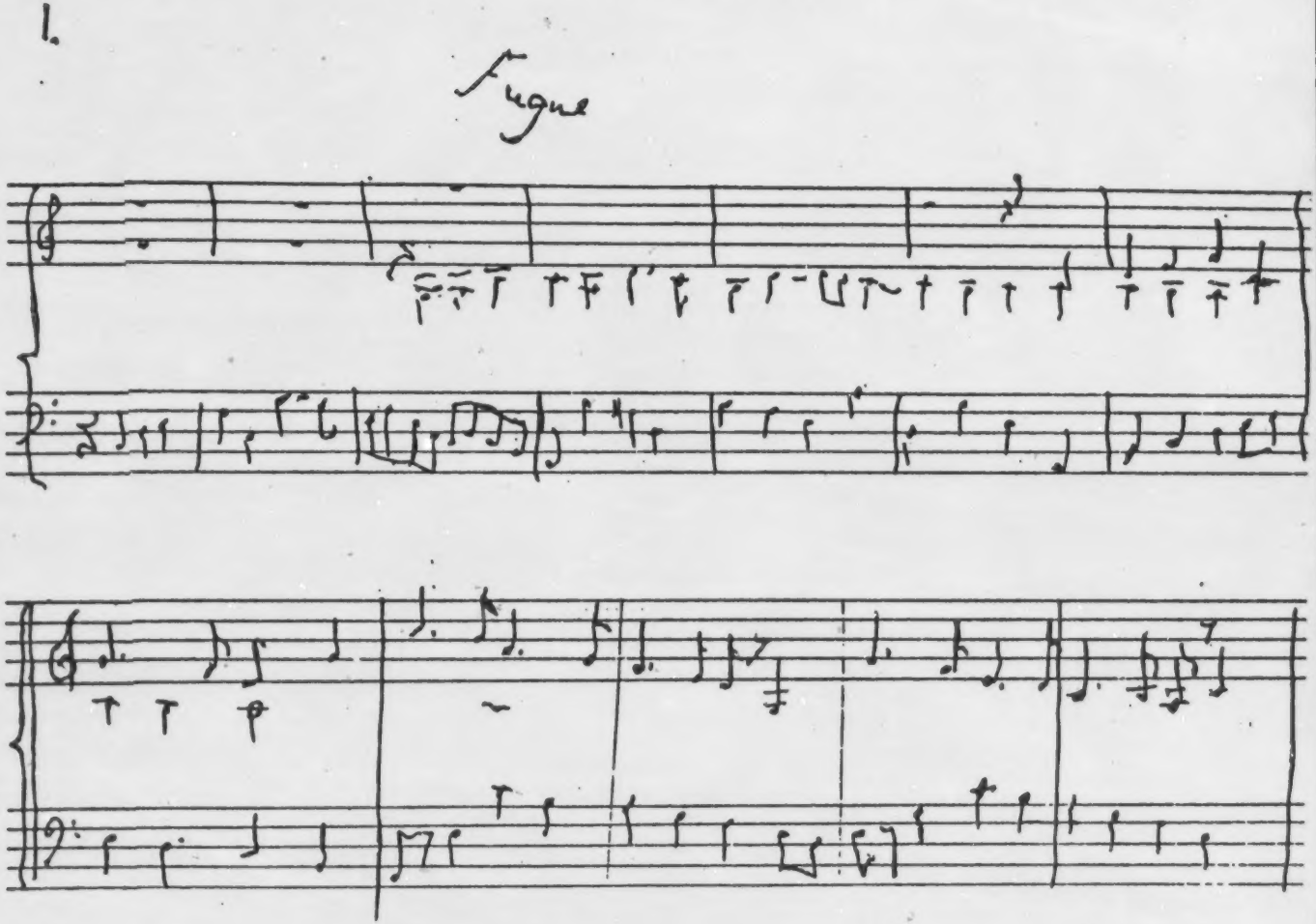
III. DISCUSSION

We have presented here the case of a 77 year old composer with a severe reading disorder as the consequence of a cerebral vascular accident. His right homonymous hemianopsia, his severe alexia, his ability to read single letters and to read letters by tracing, his relatively well-preserved writing ability, his preserved spelling and comprehension of oral spelling, and his left occipital lobe lesion as confirmed by CT scan are all very similar to cases described previously in the literature and called alexia without agraphia or posterior alexia.

There are some signs that complicate the picture, however. He has some diplopia on downward gaze and a

FIGURE 7. FIRST PAGE OF FUGUE BY B. L.

Reduced by 25%.



tendency towards right visual neglect. He has a slight anomia, a mild memory impairment, a decreased ability to handle numbers, and a tendency to confuse body parts. His handwriting tends to deteriorate when he becomes fatigued. He is slowed in practically all of his activities. Some of these signs are doubtless the joint consequence of his age and his lesion, while others, such as the components of the Gerstmann Syndrome, suggest that his lesion may extend into the left parietal lobe. Thus he shows mild symptoms of central alexia or alexia with agraphia.

Levine and Calvanio (1978) have called our patient's condition "simultanagnosia-verbal alexia." While rejecting explanations based on a primary visual defect, a material-specific agnosia, or a general insufficient visual feature discrimination, they suggest that the deficit consists of an impairment in "the identification of a compound array consisting of multiple identifiable components, where misidentification of any component will usually impair identification of the array." This description and the term "simultanagnosia" have some limited validity as a description of the patient's condition in the context of their experiments, but as a general description of his visual-perceptual style (as the term was originally used by Wolpert (1924)) it is clearly inappropriate, as our work has demonstrated. First, his music reading seems to improve, if anything, given more symbols and context on the page. Second, he performs well on a number of visual perception and construction tasks requiring the integration of separate elements including, most notably, the normal perception of subjective contours.

Finally, there may be a sense in which increased context improves his language reading, as well. The tests which most clearly demonstrate an impairment in his ability to read letters in a context of letters (as opposed to letters in isolation) used upper case letters. Upper case ("block") letters, unlike lower case letters, are of uniform height and therefore give less information about their identities on the basis of their spatial relationship to the printed context. Most of these tests also used non-words. Non-words do not conform to expected word-shapes and do not allow for much inference of letter identities on the basis of context. In fact, the patient identified almost twice as many letters when they were in a word context as compared to a non-word context (Levine & Calvanio, 1978). Finally, the patient's reading of lower case connected prose, although quite impaired, was much better than one might have predicted on the basis of his letter- and word-identification performance, and he displayed considerable inferring from context.

Our patient is ideally suited for an investigation of music reading. As a composer and professor of music he was well practiced in many different ways of reading music. Investigation of his other musical abilities revealed that aside from slowness, memory difficulties, and occasional mild clumsiness at the keyboard with the right hand, he had no specific musical difficulties which might be expected to interfere with or confound an investigation of his music reading.

The patient uses music-reading daily in a wide variety of ways, but text reading now plays very little role in his life. Aside from this practical description, however, it is difficult to compare his music and text reading skills in order to say which is more impaired. If we compare his ability to name the symbols in each system he seems to be equally impaired or, if anything, worse at naming musical symbols. If we compare his ability to read unfamiliar material we find that he makes errors on short phrases in either sphere and performs at the elementary school level in both. If we compare his ability to read familiar material we find that he can recognize familiar melodies better than their titles, but he is able to orient himself to the overlearned poem he is using for a text of a composition perhaps as well as to a familiar piece of music. If we compare his ability to play notes from a written page of letters or musical notes we find that he is clearly worse when playing from letters, but this task is confounded by the fact that the letter task is an uncommon and unpracticed one. In fact, the differences in his use of music and text reading in his daily life may reflect the different uses to which the two systems are usually put more than anything else.

One difference between the two spheres is clear, however. Levine and Calvanio (1978) have clearly demonstrated (and we have confirmed) that at least under some circumstances this patient's ability to read single letters is greatly impaired by the presence of other letters. But exactly the opposite seems to be the case for music reading. Whereas musical symbols or notes isolated on the page are poorly or slowly identified or played, those same symbols or notes are generally more accurately identified and more rapidly played in their appropriate context.

This difference must at some level indicate something distinctive about the organization of the brain or the nature of alexia, but it is difficult to say at what level. Despite their common features, English text and staff music notation differ in major ways graphically, symbolically, and functionally. Graphically, letters are about the same size and are placed fairly evenly on the page with spaces between them and occasional punctuation marks. Musical symbols vary

widely in size, are spaced erratically but meaningfully on the page and are connected by lines. The variations in size give another dimension along which to identify symbols besides their position and shape, thus making them more salient, while the lines provide a frame of reference making it easier to appreciate the relative positions of the symbols.

Symbolically, letters are phonetic and have an arbitrary and rough correspondence to speech sounds/gestures. Other symbols, both phonetic and ideographic, are few and far between. Musical notes are also phonetic, but their positions have a non-arbitrary (ordinal) relationship to musical pitch and duration. Other symbols are common and ideographically represent ideas at a variety of levels. Furthermore, the category of a symbol can often be identified on the basis of its relative size and position independently of its specific shape. For instance, clef signs are usually at the beginning of the line or following double bars; tempo indications are above the staff and usually on the top line on the left; dynamics are indicated beneath the staff; and notes are on the staff lines or connected to them by stems and ledger lines.

Functionally, a fluent and knowledgeable reader of of English text and staff music notation such as our patient might have available a wider and certainly a different set of associations for music notation than for text. A word can be read by sounding it out phonetically either out loud or in auditory and/or motor imagery. It can be read directly as a visual-motor and/or visual-auditory association as in look-say vocabulary. It can apparently be read as a direct visual-semantic association as Kanji readers report. Or it can be read (or ignored) by inference from the linguistic context like the double "of" in the first sentence of this paragraph. Music notation has many of these forms of association available, but it has other common associates, too. There are multiple motor associates available for singing and various instruments, instead of essentially just one for speech and one for writing. There are multiple verbal associates as in solfeggio syllables, note names, interval names, chord names, and the names of the other symbols. There are pure auditory associates, and there may be other associates, for instance, theoretical associates.

Our evidence tentatively suggests that all three of these levels of differences between music and text reading play some role in our patient's different performances in the two modes. That graphics are important is suggested by his tendency to make errors involving visual confusions. Substitutions that are morphologically similar were seen in letter identification (e.g. O for Q or C, W for V or N,

etc.; see Levine and Calvanio (1978) for a detailed analysis) word identification ("for" for "from," "reading" for "radio," "eat" and "earn" for "earth") and note reading (errors of a musical third).

The importance of the symbolic differences between English text and staff music notation is indirectly supported by the evidence for the importance of such differences in Japanese aphasics. It is also supported by his self-proclaimed use of the ordinal features of pitch notation in reading lines of notes by their successive intervals. This introspection is supported by the result that notes presented vertically on separate staves were played slower than notes presented horizontally on the same staff. His tendency to make errors of transposition by the interval of the initial error also speaks for the importance of the specific nature of the symbolism.

The importance of the functional differences between music and text is supported by the fact that he was generally faster and better at performing from music notation than at naming symbols or notes.

This evidence is slender, however, and the relative importance of each of these levels in producing dissociations between music and text reading in various disorders remains to be determined. The observation made above, that alexics with well-preserved music reading tend to have primary language disorders, suggests that in these cases functional factors are very important. In Assal's (1973) case, for example, music reading was unimpaired except when a verbal response was required. The roles of graphic and symbolic factors might be elucidated by the study of patients trained in other music notation systems such as guitar, lute, or koto tablature, or the cipher systems of elementary education, guitar notation, and Indonesian gamelan. (I have seen one case of a central alexic who was able to play guitar chords from tablature or letters although unable to name the letters.)

Our results demonstrating considerable sparing of music reading abilities in a patient with posterior alexia are at considerable variance with other reports of music reading abilities in posterior alexics (Dejerine, 1892; Poetzl, 1927; Holmes, 1950; Levin & Rose, 1979). Although the limits of the examinations in those cases might be the source of the discrepancy, several other factors may be involved, as well. First, our patient is a composer with great premorbid skill in music reading and many music reading strategies available, while the cases cited were amateurs with uncertain musical skills. The exception is Levin and Rose's case who was a drummer but who may have never learned to read music, or at least pitch notation, or may not have

learned it well. Second, our subject was actively engaged in reading music up to the very moment of the stroke, and he had begun to practice reading music again before we saw him. Most of the cases cited above did not report if the patient was in practice. (The possibility that the differences in music- and text-reading in our patient are due to practice effects can be ruled out by the fact that he had months of language reading therapy and practiced reading text daily.)

There are, however, precedents in the literature for several of the phenomena we have observed. Assal and Hadj-Djilani (1976) reported a case of good music reading in a posterior alexic. Most of the other reports of sparing of music reading in alexia have used performance as a measure, whereas most of the reports of loss of music reading with alexia have used note- and symbol-naming as a measure. Levin and Rose (1979) reported an effect of improved musical symbol identification in a musical context, and Dejerine (1912, cited in Benson & Geschwind, 1969) reported an effect of improved non-musical symbol identification with the addition of context. Bouillaud (1865), Anton (1888), Assal (1973), and Luria, Tsvetkova and Futer (1965) all reported cases in which musical creativity was preserved in the face of left hemisphere damage.

What do the results imply about our hypotheses?

1) A visual-perceptual disorder. Our patient had a right hemianopsia, a mild right visual neglect, possibly disordered eye movements, and a diplopia on downward gaze. All of these certainly contributed to some extent to his disability. The evidence suggesting that differences in the graphic features of English text and staff musical notation were important in producing the differences observed between music and text reading would support this hypothesis. Yet such an explanation alone will not account for the variations in performance seen with changing task conditions and the same stimuli, nor do they seem likely to account for all of the data in light of his good performance on various perceptual tasks.

2) A visual symbol recognition disorder. Similarly, the differing performances under different task conditions and also the effects of context on performance suggest that the problem lies not only in symbol recognition but also in symbol interpretation or use.

3) A visual-verbal disconnection. This hypothesis is largely supported by the evidence. It accounts not only for the alexia but also for the poor naming of musical symbols, while leaving open the possibility of preserved music reading for performance. It leaves unexplained his poor performance in playing notes from their printed letter names, but this might be explained on the basis of his

unfamiliarity with the task and the possibility that for him it was necessary to represent the letter to himself verbally before being able to play the appropriate note. It also leaves unexplained his impairment in sight-reading music for performance, but here his perceptual difficulties might be invoked. His good color-naming presents a problem for this hypothesis. The effects of context on letter-identification remains unexplained.

4) A disconnection of visual input from portions of the left hemisphere concerned with processing sequential material. The relative preservation of music reading for performance presents problems for this hypothesis, although it might be argued that memory and inference are playing an especially strong role in that situation. This hypothesis could not account for his impaired ability to read single notes. This hypothesis cannot be ruled out.

5) A disconnection of visual input from areas responsible for "pure" visual-auditory associations. As we have seen, music reading for the skilled reader involves much more than "pure" visual-auditory associations. Therefore, the relative preservation of many forms of music reading in this patient does not present a problem for this hypothesis. However, an impairment in sight-singing as compared to sight-reading at the piano might have been expected, but it was not observed. This hypothesis would not explain the effects of context on letter identification, or his good color naming.

6) A disconnection of visual input from areas responsible for skilled fine motor performance. This hypothesis would predict poor music reading for performance. It also requires a motor theory of text reading. A preservation of semantic or ideographic reading might have been expected. The hypothesis might be salvaged by claiming that speech is a more difficult motor task than musical performance, but further evidence on this point would be required. Impairment on visually- guided skilled tasks might also be expected, but this was not tested.

We have not been able to rule out any of our hypotheses entirely. The first two perceptual hypotheses have been found to be inadequate as complete explanations. The disconnection hypotheses seem better, but none of them is completely satisfactory. The apparent superiority of the visual-verbal disconnection hypothesis seems disconcerting in that it does not allow us advance to a more neurologically relevant account. Instead of discussing primary sensory and motor deficits, we have found ourselves invoking increasingly cognitive and theoretical explanations of the phenomena we have observed.

Yet in the long run this may prove to be the more neurologically relevant approach. The reason for this is that

these explanations place a greater and greater importance on the patient's history, that is, on the sequence of development of the nervous system. Concepts such as sequential information processing, fine motor skill and pure visual-auditory associations may ultimately prove most useful in explaining why certain human cognitive activities come to be structured as they are. They may be the initial predispositions of different cortical areas that result in certain activities being concentrated in circumscribed cortical areas, the initial small rivulet that evolves into a canyon. Thus we cannot assume that, because our patient was poor at playing notes from their written letter names, that it is because there is something wrong with the visual-motor pathways or their endpoints. Rather, we have to take his history into account and note that that was not a highly practiced skill. His only available strategy for this task may have been a more circuitous cerebral route. And it is primarily on the basis of histories that we are able to suggest a reconciliation of our results with those in the literature. Our brains have evolved to have considerable learning capacity. Just as it is reasonable to expect that we should come into the world with brains whose characteristics are best described in neurological terms, so it is reasonable to expect that after a lifetime of use their structures will best reflect those patterns of use.

What about the neuroanatomy of music reading disturbances? Music reading disturbances are often the result of left hemisphere lesions, as is clear from this case and others reviewed above. Language reading disturbances are often associated with these musical alexias. Undoubtedly this association is due in at least some cases to a more general visual-perceptual disorder (Martin, 1956), but this explanation probably does not extend to all cases (for example, this one). The cases we have reviewed of musical alexia with a right hemisphere lesion also involved a significant amusia.

Barbizet (1972) has suggested that music is a bi-hemispheric activity with expression and reception taking place primarily in the right hemisphere, with the more cognitive activities of composition, memory, reading and writing being mediated more by the left hemisphere. These findings seem consonant with this view. But we must heed Hughlings-Jackson's warning and not identify the site of the function invariably with the site of the lesion producing its disturbance. Other interpretations may be possible.

Feuchtwanger (1930), Ustvedt (1937), Barbizet (1972), Gates and Bradshaw (1977), Benton (1977) and others have all taken variations on the position that music involves a complex set of behaviors probably involving many parts of

the brain and both hemispheres. The evidence is mounting to suggest that these authors' views are correct. But at the same time it appears unlikely that musical functions will break down simply into Barbizet's (1972) scheme of perception and expression on the right, reading, writing, composing, memory, and theory on the left. Music reading alone can involve a variety of activities with a number of strategies available for each. We have seen that these activities can be differentially effected by a unilateral brain lesion. B.L.'s symptoms suggest that the left hemisphere is important in naming musical symbols. His use of context and his sight-reading may reflect right hemisphere functioning. It seems likely, then, that the roles of the cerebral hemispheres and various areas within those hemispheres in music reading will depend heavily upon the nature of the activity and the particular history of the patient. This is a discouraging outlook from a research perspective since it makes it much more difficult to compare cases, but nature did not put together our brains with the intention of allowing us to figure them out easily.

Although opportunites for treatment of disorders of musical abilities are rare, our experiences in this area may eventually prove helpful to someone else. The switchover to wide-lined staff paper proved to be of considerable benefit to our patient. It avoided many misplaced notes and made his music much more readable. The investigation itself was also useful in that it made him more aware of his strengths and limits and helped him to explore different strategies for dealing with the limits. He found that the composition exercises were also useful in getting him back into shape for composing after a year's silence. He found a tape recorder very useful for learning the texts he was setting, for recording musical ideas for later transcription, and for occasional correspondence and listening to "Talking Books for the Blind." He also found an assistant quite useful in helping him to keep up his correspondence and to some extent his composing by dictation and in transcribing working drafts of new pieces.

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Harvard Project Zero is a basic research program at the Harvard Graduate School of Education. Its original charge was to study creation and comprehension in the arts and means toward better art education. A prime objective throughout the Project's history has been to provide a sound theoretical and experimental base for effective education of artists and audiences. The Project began in the fall of 1967 in response to the frank admission that, however much is known about how to educate in science and how to evaluate scientific work, practically nothing is known about the underlying principles of how to teach and evaluate in art. From that challenging "zero" the Project took its name and tasks. Our research methods include rigorous conceptual analysis, investigation of relevant literature, design and execution of key experiments in psychology and other fields, visits to arts education institutions, and application of results to proposing and assessing programs in art education.

Project founder and former director Nelson Goodman's book Languages of Art (Bobbs-Merrill, 1968) has provided important direction in our effort to isolate and investigate basic skills. This work sets forth a "theory of symbols," a broad treatment of elements of communication, embracing words, gestures, diagrams, paintings, poems, musical scores, and so on. Almost all the psychological processes under consideration in our studies of the arts involve extensive operation with and upon symbols of various kinds. These symbols are not merely instruments of communication, but also instruments of cognition, tools in terms of which the mind deals with the perceptual world.

Some of our research has examined the psychological implications of the theoretical models of symbol systems introduced in Languages of Art. For instance, one question is whether different information processing skills are necessary to produce effective art within linguistic, versus nonlinguistic, symbol systems. Another, complementary approach emphasizes problem solving and search strategies in the moment-to-moment perception and production of a work of art. How do subjects search for rhyme words in poetry or explore alternative placements of pieces in collage? A favorite means of developing and testing new models is through the study of errors. By using impoverished or ambiguous stimuli, assigning tasks somewhat too difficult for a subject, or working with brain-damaged subjects, one can elicit patterns of error-making which suggest hypotheses and select between alternative models of a process. These approaches characterize many of the Project's investigations mentioned below in a list of Project members and their particular interests.

Though the development of actual curricula in arts education is not a primary concern, the Project does contribute to the field of practical education. Project members have responded to inquiries and requests to comment on curricula from teachers in the field. Establishment of Harvard Summer School's Institute in Arts Administration resulted from the Project's reply to an inquiry from the director of the Harvard Summer School, and members of the Project staff cooperated in planning the Institute, in preparing material, and in the actual teaching. Consideration consultation has been provided to schools, museums, television, and a variety of arts institutions by members of the Project.

The Project has also sponsored a series of lecture-performances in various media, designed to give the general public and prospective public school teachers and administrators better insight into and attitudes towards artists and the arts. As the series title "Art in the Making" suggests, the purpose of the lecture-demonstrations was to reveal something of the artist's way of working, rather than to display his products. In the presence of an audience free to ask questions, each artist explored alternatives, exposed some constraints of his medium, compared his various efforts, and searched for the right effect, choice by choice.

While maintaining a major concern with the arts and art education, the Project, under its current co-directors, has considerably broadened its field of inquiry and now investigates a whole range of topics in the area of cognitive psychology. One part of the Project has focussed particularly on developmental studies. Among the topics currently being investigated are the emergence of symbolic capacities during the first years of life; the development of literary abilities, specifically the capacity to produce and appreciate metaphors and stories; children's understandings of the various worlds presented on television; the emergence of drawing skills; and the breakdown of various symbol using capacities under various forms of brain damage. The other part of the Project has concentrated on studies in the areas of cognitive and perceptual psychology, ones which utilize both normal adult subjects and gifted artists. Among the topics investigated recently have been critical judgment and the sources of critical disagreement in adults; the thought processes of professional and amateur poets and painters in developing works; the role of geometric principles in visual perception and picture perception particularly; reasoning about everyday matters and the logical difficulties people encounter.

A list of recent papers which can be purchased from the Project is available upon request.